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AUTOMOTIVE COMPUTER CONTROL SYSTEMS

William L. Husselbee

TECHNOLOGY PUBLICATIONS

Automotive Computer Control Systems

Fundamentals and Service

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To my wife, Laurie, whose patience, understanding, and clerical assistance made this project possible.

PREFACE

Automotive repair technicians are now faced with what is probably the greatest challenge since the introduction of the automobile—the testing and repairing of the microcomputer engine control systems found on automobiles. The computerized system has all but replaced a number of basic engine control functions that were once handled by mechanical or pneumatic automatic devices. The change to microcomputer engine control systems resulted from emission and fuel economy standards that the vehicle manufacturers had to meet.

To people working in the field, computerized control systems may seem very complex and difficult to understand, requiring the skill of an electronics expert more than an automotive technician. However, this is not true. Although computerized systems are complicated and often require different methods of diagnosis and repair, they are all fixable. As with any other automotive system, common sense, logic, and a knowledge of how the system functions are the most important tools the technician can have.

This textbook is designed to provide that knowledge. It is arranged to guide the reader through computerized engine control systems from the basic operating principles to the testing and repair of the complex systems used in modern automobiles and light trucks. The chapters are arranged in the order they should be studied, the early chapters providing the groundwork for the later ones. The first four chapters, for example, deal with the need for electronic engine control systems, electrical fundamentals, electronic fundamentals, and automotive computers. Without mastering this information, the rest of the text will be difficult to comprehend.

Chapter 6 deals with shop tools and procedures. This information is introduced before any material on the subsystems under microcomputer control are discussed. The reader will, therefore, be ready to use correctly the various types of equipment called for to test subsystem and microcomputer circuits and components. These circuits and components are usually very expensive, and the improper use of test equipment or an inaccurate diagnosis can quickly destroy them.

Chapters 7 through 17 break down the computerized engine control system into smaller units, or subsystems. Before the advent of microcomputer control, these were all considered to be separate engine systems. A chapter on the design and operation of a particular subsystem is followed by one on how to troubleshoot it for malfunctions. In these later chapters, special emphasis is placed on the use of diagnosis charts and step-by-step procedures along with such basic test equipment as the voltmeter and the ohmmeter. In the ignition service chapters, scope pattern diagnosis of the various systems is clearly explained.

Chapters 18 through 23 provide data on specific, computerized engine control systems produced by Ford, General Motors, and Chrysler. Each system is covered fully, enabling the reader to form a complete picture of system design and function. Such an understanding should make the diagnosis easier. Because most imported systems are similar in design and operation to those presented in Chapters 18 through 23, only typical domestic computerized engine control systems are covered in this book.

Each of the system theory chapters is followed by one on service. The service chapters cover detailed procedures for troubleshooting and repairing typical systems, including how to access service codes and properly use driveability, quick, and pinpoint test procedures. If the technician is not fully aware of what a particular test is attempting to measure, what the normal readings should be, and what conditions cause abnormal results, a correct interpretation of diagnostic procedure directions can be difficult.

In designing this book, the author assumed that the reader was already familiar with the basic principles of internal combustion gasoline engines and their fuel, lubricating, and cooling systems. Therefore, these principles are not explained in this

text. Moreover, this textbook is not intended to replace manufacturer's manuals or aftermarket technical service publications. This book supplements these materials by providing additional information about how the systems are designed and operate, and practical instruction about how to interpret the manufacturer's service and testing procedures.

SAFETY PRECAUTIONS

This text contains various general and specific safety precautions that must be read and understood in order to minimize the risk of personal injury or damage to the vehicle or its components from incorrect service procedures. The author could not possibly know, evaluate, and advise the service industry of all the conceivable ways in which service or repair may be carried out or of the many possible hazardous consequences of an unorthodox method. Accordingly, anyone who uses any service procedure must first satisfy himself or herself that the use of a procedure will neither jeopardize personal safety nor damage the vehicle. When in doubt as to how to use a given tool or piece of equipment, or how to perform a given service procedure, always refer to the appropriate manufacturer's instructions or vehicle service manual.

TEACHING AIDS

This text incorporates a number of teaching aids. Each chapter is preceded by a number of objectives that spell out what the reader should know or be able to do after reading and studying a given chapter. In addition, all chapters have self-check and review sections at their conclusion to assist the reader in determining how well he or she remembers the material in the chapter. All the self-check and review questions or statements are based on chapter objectives and are keyed to the sections from which they come.

Although they are not actual Automotive Service Excellence (ASE) test questions, the review questions or statements found in service Chapters 7, 9, 11, 13, 15, 17, 19, 21, and 23 are similar in format. ASE questions are generic in nature, while the ones presented in these chapters test the reader's knowledge of a system specific to a single make of automobile. ASE is a nonprofit institute that prepares, administers, and grades tests for the voluntary certification of automotive, heavy-duty, and auto body technicians. ASE certification is the most valuable credential available to service technicians because (1) the ASE tests are tough and passage of any one of the specialized area tests demonstrates that a technician is among the elite of his or her profession and (2) ASE credentials are recognized throughout the nation.

Each chapter has a generous number of illustrations. They help in explaining components or systems as well as service procedures. And each illustration has a brief explanation that ties it to the text material.

ABOUT THE AUTHOR

The author has 31 years of experience in the industry in the following areas: automotive machinist, automobile mechanic, service advisor, tune-up technician, automotive instructor, and technical writer. This experience is reflected in the practical approach to the subject matter along with the content and design of this book. Finally, the author is an ASE certified master automotive technician and a member of the National Association of College Automotive Teachers (NACAT) and California Automotive Teachers (CAT).

ACKNOWLEDGMENTS

The author wishes to thank Chrysler Motors Corporation, Ford Motor Company, Sun Electric Corporation and General Motors Corporation for the use of material and illustrations in this text.

The author must also express appreciation to the reviewers whose comments and criticisms have greatly enhanced this book: William M. Dempsey, National Institute for Automotive Excellence; Max J. Morley, Anchorage Community College; Rick Escalambre, Skyline College; Ted Nicoll, Central Missouri State University; and Steve Stillwell, Central Piedmont Community College.

Also, the author would be grateful for information from readers on errors or omissions in this book.

William L. Husselbee

CONTENTS

Automotive Computer Control Systems

Chapter 1

NEED FOR ELECTRONIC CONTROL OF ENGINE OPERATION

OBJECTIVES

After reading and studying this chapter, you will be able to

- explain the function of engine controls.
- describe the differences between primary and secondary engine controls.
- explain the three harmful emissions that an engine produces.
- describe what an information processor does and the drawbacks to mechanical or pneumatic types.
- explain how electronic engine controls can increase engine power, improve vehicle driveability, reduce emissions levels, and improve fuel economy.

1-1 PRIMARY ENGINE CONTROLS

Automobile engines have always had a number of primary control devices. Basically speaking, *primary engine controls* are mechanisms used to regulate the operation of the power plant so that it can function in an efficient and predictable manner. For example, the carburetor is a control that governs the engine's air/fuel ratio and speed, while the distributor directs ignition system operation and spark timing (Fig. 1-1).

Over the years, the automobile industry has used hydraulic, mechanical, and pneumatic controls. By the mid-1960s, these controls had become quite sophisticated. However, the only electrical primary control, used before the mid-1970s, directed the operation of the ignition system.

Factors Relating to the Control of Engine Operation

When viewing the control of engine operation, there are four factors to consider: (1) power, (2) vehicle driveability, (3) emission levels, and (4) fuel economy. Before the mid-1960s, the automobile industry designed and produced vehicles with controls that promoted the first two factors, power and driveability. This was due primarily to the public's taste and driving habits.

As a result, the majority of automobiles at that time were large, heavy, and equipped with high horsepower engines that produced a lot of power and provided great vehicle driveability. But these engines consumed a lot of fuel and produced high emission levels.

However, neither of these problems was of much concern then. After all, fuel was cheap and readily available. Moreover, although recognized as a problem, harmful engine emissions were not as yet subject to strict controls.

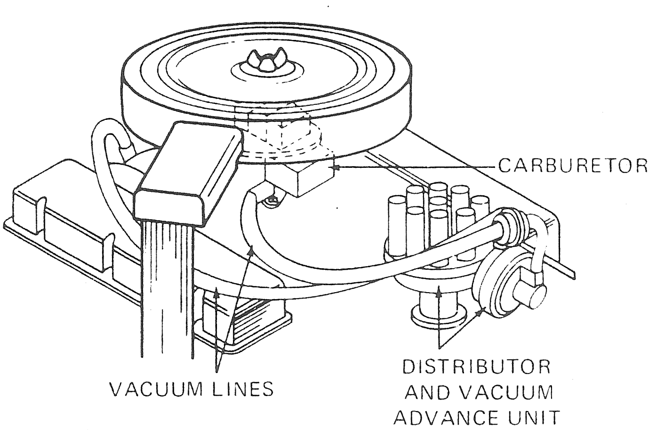


FIGURE 1-1
Primary engine controls, the carburetor and distributor.

MODEL YEAR	HYDROCARBON (HC) CALIFORNIA	HYDROCARBON (HC) FEDERAL	CARBON MONOXIDE (CO) CALIFORNIA	CARBON MONOXIDE (CO) FEDERAL	OXIDES OF NITROGEN (NO_x) CALIFORNIA	OXIDES OF NITROGEN (NO_x) FEDERAL
1978	0.41	1.5	9.0	15.0	1.5	2.0
1979	0.41	0.41	9.0	15.0	1.5	2.0
1980	0.39	0.41	9.0	7.0	1.0	2.0
1981	0.39	0.41	7.0	3.4	0.7	1.0
1982	0.39	0.41	7.0	3.4	0.4	1.0
1983	0.39	0.41	7.0	3.4	0.4	1.0
1984	0.39	0.41	7.0	3.4	0.4	1.0
1985	0.39	0.41	7.0	3.4	0.7	1.0
1986	0.39	0.41	7.0	3.4	0.7	1.0
1960 (No Control)		10.6		84		4.1

FIGURE 1-2
Federal vehicle emission requirements in grams per mile. (Courtesy of Chrysler Motors Corp.)

During this era, vehicle designers and engineers also did not have to concern themselves with complicated primary engine controls. Engines operated well on relatively rich mixtures that were rather simple to maintain. The basic hydraulic, mechanical, and pneumatic controls built into the carburetor and distributor, which had been in service for years, still remained adequate for the job.

In fact, there is one main reason it took so long for electronic controls to be adapted to the automobile engine. The automobile industry was reluctant to give up a well-understood and well-defined primary control technology to embark on the potentially risky program of implementing the use of electronics.

Legislated Emission Standards

But in the late 1960s and early 1970s, the third factor, emission levels, entered the picture. California and the federal government, responding to ever increasing levels of airborne pollution, began to pass emission control standards for motor vehicles. Figure 1-2 shows federal and California emission standards, using 1978 as a base. Notice that for 1980 and 1981, emissions standards decrease sharply the allowable limits.

As a result of the new standards, automobile manufacturers embarked on a program of federally mandated change. For the first time, auto companies had to seriously consider emission levels during engine operation. These standards have been effective in curbing high emission levels of motor vehicles by forcing manufacturers to adjust engine calibrations by leaning air/fuel mixtures, altering spark timing, and even redesigning the power plant itself.

1-2 SECONDARY ENGINE CONTROLS

In addition, the industry installed additional devices when it became apparent that the primary ignition and fuel system controls were insufficient to reduce emission levels alone. Therefore, these *secondary engine controls* were primarily for the purpose of further reducing harmful emissions and operated either mechanically, pneumatically, or electrically.

Typical secondary engine controls or systems installed on vehicles include the

- positive crankcase ventilation (PCV) system,
- air injection system,
- exhaust gas recirculation (EGR) system,
- transmission controlled spark (TCS),
- evaporation emission control (EEC) system,
- catalytic converter system, and
- thermostatic air cleaner (TAC).

Types of Emissions Controlled

These devices reduce three of the harmful emissions produced by an automobile engine. These include hydrocarbons, carbon monoxide, and nitrogen oxides, all three of which are under federal control standards.

Hydrocarbons (HC) are the chemicals that make up gasoline. They are made of different combinations of hydrogen (H) and carbon (C). Hydrocarbon emissions are the product of unburned gasoline from blow-by gases, unburned gasoline from the engine crankcase, fuel evaporation losses, or a misfire condition within a cylinder (Fig. 1-3). The misfire can result from a mechanical, electrical, or air/fuel ratio problem. The latter is characterized by a portion of the charge being too rich or too lean to burn at all.

Carbon monoxide (CO) is a gas consisting of carbon and oxygen. This colorless, odorless, poisonous gas is the product of the combustion process within the engine (Fig. 1-4).

During ideal combustion, the carbon and hydrogen in the gasoline combine with oxygen from the air, releasing heat energy and forming various chemical compounds. If the combustion is perfect, the exhaust gases consist of carbon dioxide (CO_2) and water (H_2O), neither of which is considered harmful in the atmosphere.

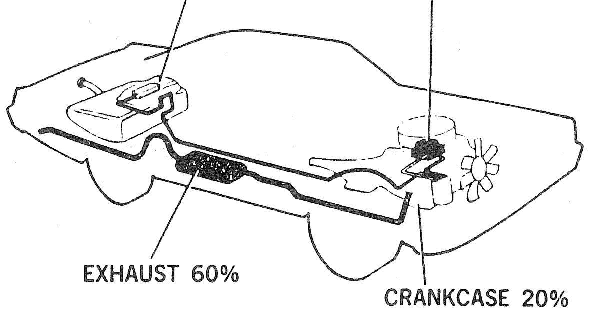


FIGURE 1-3
Sources of hydrocarbon emissions from an automobile. (Courtesy of Chrysler Motors Corp.)

Unfortunately, combustion in the internal combustion engine is not perfect. Consequently, in addition to the CO_2 and H_2O, the exhaust contains a quantity of CO. The problem becomes worse whenever the air/fuel ratio is richer than about 15:1 because there is less oxygen present in the charge to complete the combustion process. The lack of oxygen decreases the conversion of carbon to carbon dioxide.

Therefore, carbon monoxide levels are very dependent on the air/fuel ratio. This, in turn, depends to a great extent on the calibration of the carburetor. The leaner the mixture the carburetor provides, within a certain range, the more oxygen there is available to reduce CO emissions.

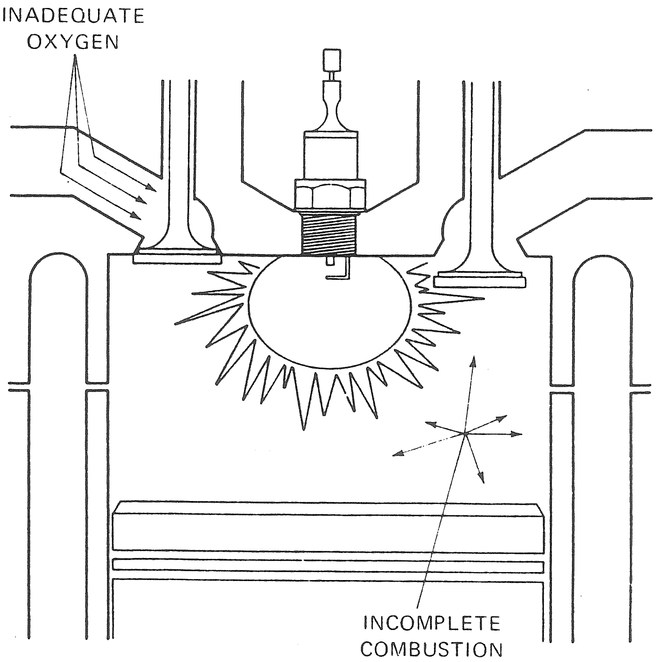


FIGURE 1-4
Carbon monoxide is the result of incomplete combustion.

Nitrogen oxides are gases consisting of nitrogen from the atmosphere that combine with varying amounts of oxygen under the high temperature and pressure conditions found in the internal combustion engine (Fig. 1-5). The high temperatures necessary to form NO_x, above 2,500°F, only occur during some phases of engine operation. (*Note:* NO_x is the symbol representing any combination of nitrogen and oxygen. The x symbolizes any number of oxygen atoms in the gaseous compound.)

When an engine is operating, atmospheric air moves through the carburetor where it mixes with fuel before entering the engine. Under normal conditions, the combustion process consumes the oxygen from the air, while the nitrogen passes out of the exhaust virtually unchanged.

However, during the combustion process, temperatures may exceed 4,500°F. At temperatures above about 2,500°F, nitrogen oxides form very rapidly from the nitrogen and oxygen in the air. Consequently, the formation of NO_x is dependent on temperature. Any variable that causes an increase in temperature above about 2,500°F will increase NO_x emissions.

Effect of Emission Control Standards on Vehicle Driveability

Engine power was lost and vehicle driveability did suffer slightly as a result of leaner mixtures, timing recalibrations, internal engine changes, and the addition of the early types of secondary controls. These negative effects were in opposition to the public's passion for big, fast automobiles. Vehicle driveability includes everything that the driver expects from a properly operating engine, such as easy starting (hot or cold), acceptable smoothness at idle, good acceleration in all speed ranges, instant response, and full power.

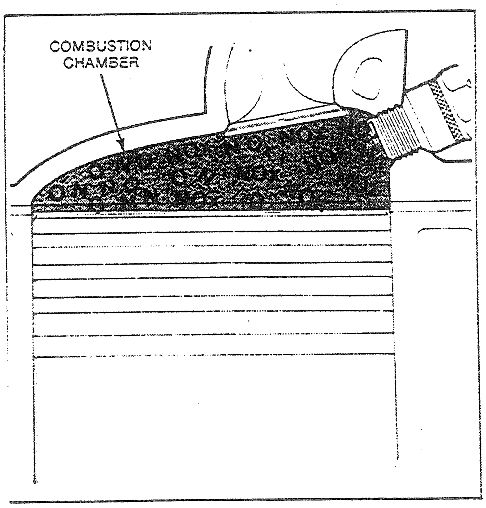


FIGURE 1-5
Nitrogen oxides form in the combustion chamber under high temperature and pressure.

MODEL YEAR	MPG	IMPROVEMENT OVER 1974
1978	18.0	50%
1979	19.0	58%
1980	20.0	67%
1981	22.0	83%
1982	24.0	100%
1983	26.0	116%
1984	27.0	125%
1985	27.5	129%
1986	27.5	129%

FIGURE 1-6
Fuel economy standards. (Courtesy of Chrysler Motors Corp.)

But manufacturers still considered their hydraulic, mechanical, pneumatic controls adequate for the task because driveability was not all that bad. Moreover, it was always possible to make an engine larger to compensate for the power loss. Finally, despite the fact that the larger, recalibrated emission-controlled engines of this period used more fuel, the operating costs were still within the range of most people. Therefore, there was still no need to make any basic changes in the primary engine controls.

1-3 LEGISLATED FUEL ECONOMY STANDARDS

In the early 1970s, another large problem occurred that directly affected the driving public and the automobile industry. This, of course, was the fuel shortage, which caused gasoline prices to skyrocket.

To reduce the use of fuel, the federal government mandated fuel economy standards, or requirements, to all vehicle manufacturers (Fig. 1-6). Federal fuel economy standards are based not only on a single automobile but also are stated in terms of average rated miles per gallon (mpg) fuel consumption for all production models by a manufacturer in any given year. It is a somewhat complex requirement that is based on the measurement of the fuel used during a prescribed, simulated, standard driving cycle that includes city and highway operation.

The mileage of any vehicle depends on many things, including size, shape, weight, and how it is driven. The best mileage is achieved under a steady

cruise condition; for example, on a highway. Good mileage is not a characteristic of city driving, with its many starts and stops. A combination of city and highway driving is used to determine the typical fuel mileage of a vehicle.

The standard itself is known in the automotive industry as the *Corporate Average Fuel Economy* (CAFE). Beginning with the 1978 model year, CAFE standards began at 18.0 mpg and gradually increased through 1986, when the industry was supposed to meet a 27.5 mpg requirement. This represents a 129 percent decrease in fuel usage from typical 1974 model vehicles.

The *Environmental Protection Agency (EPA)* monitors these fuel economy requirements. To do this, the EPA groups automobiles by model, engine size, number of cylinders, catalyst use, fuel system, and sales area (49 states or California). However, because identical engine and drive train combinations are used in many different models, the EPA does not actually test every possible combination.

As a result of the CAFE standards, the automotive industry, for the first time, had to consider fuel economy during engine operation as well as power, vehicle driveability, and emission levels. To do this, engineers had to design smaller engines for little vehicles.

Moreover, these new engines had to operate closer to the *stoichiometric*, or ideal, air/fuel ratio of 14.7:1, regardless of the usual changes in load, acceleration, and other operating conditions. As a result, the conventional engine control systems were pushed to the limit of their capacity. The only solution available was a shift from the conventional to electronic control systems.

1-4 ELECTRONIC CONTROL SYSTEM

One of the most important developments in the automotive industry has been the shift to electronic engine control systems. The contemporary, fully computerized control system constantly adjusts fuel, ignition, and emission controls during various driving conditions. The result is improved engine performance, better driveability, increased fuel economy, and lower emission levels.

Conventional Control Systems are Information Processors

To understand why the shift to electronic control has become necessary, let's take a look at the inherent limitations of a few conventional primary and secondary controls and then see how a computer overcomes them. All types of engine controls are *information processors*. That is, the control receives input information from the operating engine, processes it, and finally produces a specific output, which modifies the power plant's performance.

In what manner the control processes the information and how much it alters engine performance depends on its designer. In any case, the control comes very close to duplicating the human decision-making process by responding as the designer would to the information provided.

In addition, the action of the control is automatic. This means the device, if working properly, will process the information exactly the same way each time to produce a given change.

The centrifugal and vacuum advance units are primary controls found on a conventional distributor. Both of these devices are automatic information processors that use input data from the engine. The centrifugal advance is strictly a mechanical processor, while the vacuum unit is a pneumatic/mechanical processor. However, both units advance the ignition timing according to a given input signal.

The centrifugal advance (Fig. 1-7) uses an engine speed input signal from a spinning distributor shaft that is driven by the camshaft. The processor portion of the control consists of two flyweights of a given mass that pivot on a bracket attached to the distributor shaft and two springs. The low and high speed springs are of a calibrated tension and resist the outward movement of the flyweights due to centrifugal force.

In operation, the centrifugal advance receives the input speed signal from the engine in the form of the spinning distributor shaft. This signal causes the two flyweights within the processor to move out-

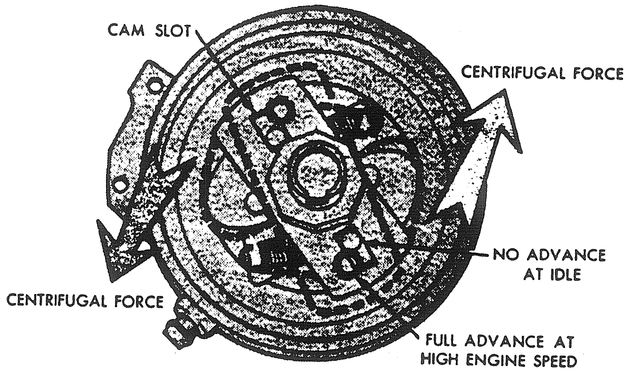


FIGURE 1-7
Typical centrifugal advance mechanism. (Courtesy of Ford Motor Co.)

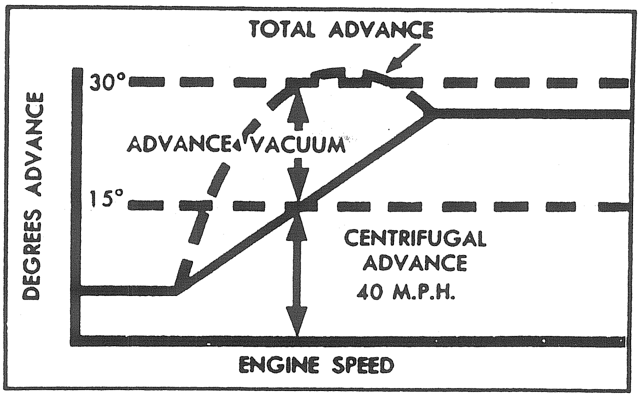


FIGURE 1-8
Timing advancement provided by the centrifugal and vacuum control units. (Courtesy of Delco Remy)

ward on their pivots due to the action of centrifugal force. The low-speed and then, in turn, the high-speed spring resist the movement of the flyweights as the distributor shaft accelerates.

At given speeds, the flyweights do move outward against spring tension. As they do, they advance the ignition timing by rotating the cam of point-type distributors, and the reluctor, armature, or timer core of electronic units. This movement is the output change that modifies the operation of the engine itself.

The amount of timing advance depends on how the processor—the weights and springs—react to the input signal. If the shaft speed (input signal) is low, there will be little or no advancement of the timing. On the other hand, with a high distributor shaft speed, the weights extend full outward in their respective travel, and the engine receives the maximum advancement built into the control. Between these two extremes, the timing will vary according to engine speed (Fig. 1-8).

The vacuum advance unit, on the other hand, uses a changing ported vacuum as the input signal to the processor. The processor itself consists of its housing, diaphragm and rod, and a spring (Fig. 1-9). The housing attaches to the outside of the distributor and has two chambers. One chamber vents directly to the atmosphere; the other connects via a line or hose to a carburetor-ported vacuum source.

The diaphragm is a piece of flexible material that is stretched between the two chambers to seal one from the other. The center of the diaphragm is reinforced with a round metal disc, where a push-pull rod attaches. The other end of the rod connects to a moveable plate that pivots within the distributor assembly.

One end of the calibrated spring bears against the center of the diaphragm; the other end is against the housing wall. The tension of the spring resists any movement of the diaphragm and rod as it reacts to changes in the ported vacuum.

When the engine is running at part-throttle conditions, there is a ported vacuum input signal at the carburetor nipple. Since one side of the diaphragm connects via a hose to the nipple, the ported vacuum acts on the spring side of the diaphragm. At the same time, atmospheric air pressure bears against its opposite side. With low pressure on the spring side and atmospheric pressure on the other side, the diaphragm moves over within the chamber against the tension of the spring.

The diaphragm movement causes the rod to move the plate within the distributor assembly a number of degrees on its pivot. This action (the output change) advances the timing by opening the points sooner in a contact system, or by advancing the position of the reluctor, armature, or pole teeth within the pickup coil of an electronic system.

When the ported vacuum is very high, the diaphragm assembly (the processor) provides the greatest amount of timing change (see Fig. 1-8). The timing advance provided by the unit varies from maximum at a high-ported vacuum to zero at idle.

Figure 1-10 illustrates a secondary engine control system consisting of the exhaust gas recirculation (EGR) control valve and a coolant control valve. The EGR valve itself is a pneumatic/mechanical, automatic-type processor that contains a diaphragm and calibrated spring. The diaphragm has a stem that attaches to a valve. The valve opens and closes passages leading from the exhaust to the intake manifold.

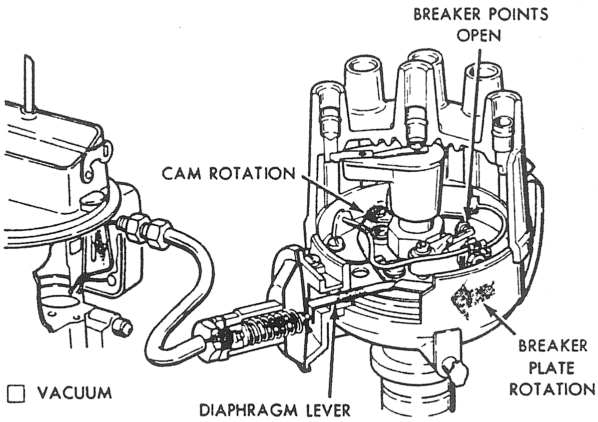


FIGURE 1-9
Common type of vacuum advance mechanism. (Courtesy of Ford Motor Co.)

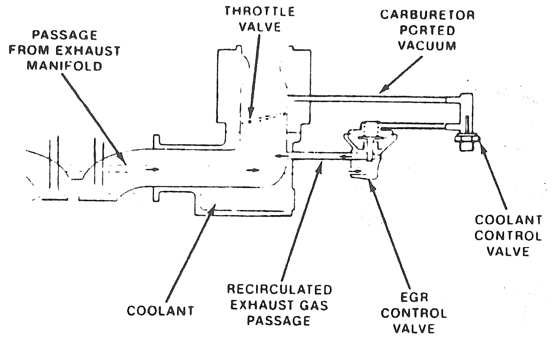


FIGURE 1-10
Typical exhaust gas recirculation (EGR) system. (Courtesy of Chrysler Motors Corp.)

The engine input signal to the EGR control processor is the ported vacuum. This signal varies from zero at idle to an intake manifold vacuum at moderate throttle settings. The signal also is near zero during wide-open throttle acceleration.

The input signal to the processor acts on the diaphragm. If the signal is strong enough to overcome spring tension, the diaphragm opens the EGR valve. Valve position, or the output change, is determined by the strength of the ported vacuum signal in opposition to the tension of the calibrated spring.

This system also has a second information processor, the coolant control switch (Fig. 1-11). The input signal to this device is coolant temperature. The temperature acts on a wax pellet or bimetallic sensing unit that operates a vacuum switch within the processor.

If the engine is cold, the sensing element allows the vacuum switch to close. This cuts off the ported vacuum signal to the EGR valve, so it cannot react to the ported input vacuum signal. When the engine is at normal operating temperature, the sensing element expands and opens the vacuum valve. At this point, the input signal can act on the EGR control valve.

Limitations to Automatic Processors

There are a number of drawbacks to automatic processors. First, the units are very inflexible. To change the manner in which one of these devices manages or processes input information, its hardware must be modified. For example, to alter the advance curve of a centrifugal unit, the mass of the flyweights or tension of the springs must be changed.

Second, most automatic processors use only one input signal. In the case of the centrifugal advance, the signal is the rotating distributor shaft. The vacuum advance and EGR control valve both act on the varying strength of a ported vacuum signal.

Third, a mechanical or pneumatic/mechanical processor produces only one output change that affects engine performance. In the case of both of the advance controls mentioned earlier, the output change was an alternation in the engine's ignition timing. The EGR control valve, on the other hand, regulated the amount of exhaust gas recirculation used to reduce nitrogen oxide emissions.

Fourth, these devices do not respond instantaneously. In other words, a mechanical processor uses too much time to process the input information before actually making a change in some performance factor. As a result, it is basically impossible for the engine to operate as efficiently as it could.

Finally, a mechanical or pneumatic processor is adversely affected by wear. Even with the same input information provided, a worn part can cause the processor section of the unit to produce the wrong output change or become inoperative. This, of course, results in poor engine performance or increased emissions.

Electronic Information Processors

In order to meet increasingly stringent federal emission and fuel economy standards, automobile manufacturers had to develop different types of engine controls to overcome the inherent problems with automatic processors. Through the use of electronic controls, the various systems of the engine can be controlled very accurately. An electronic control system uses a number of *sensors* that detect and relay input information regarding changes in engine performance and emission levels. This information is fed to a microcomputer, which is an electronic information processor called by such names as the logic module, electronic control unit, and electronic

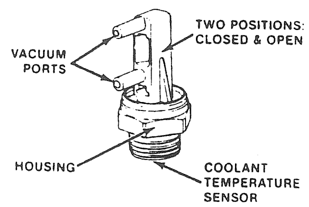


FIGURE 1-11
Thermostatic vacuum switch. (Courtesy of Chrysler Motors Corp.)

control assembly (Fig. 1-12). In any case, the input signals allow the microcomputer to monitor all engine operating conditions.

The sensors relay input information to the microcomputer by means of electrical signals. The computer processes the signals and then makes a decision regarding what system or systems need to be turned on or off. It then instantly directs electrical output signals to one or a number of control devices or actuators. Obviously, the system uses more than a single input signal and can produce multiple output changes that affect engine performance or emission levels.

When the computer signals an *actuator*, it turns a certain engine system on or off. This action very precisely controls engine operation. This, in turn, promotes vehicle driveability, decreases harmful emissions, and increases fuel economy.

There are other benefits of the electronic control system. For example, it has fewer moving parts that could wear, which allows the system to retain its calibration almost indefinitely. In addition, the system is very flexible. Because it uses electronic processors, the system can be modified through programming changes to meet a variety of different vehicle and engine combinations. In other words, critical quantities that describe an engine can be easily changed by altering data stored in the computer's memory.

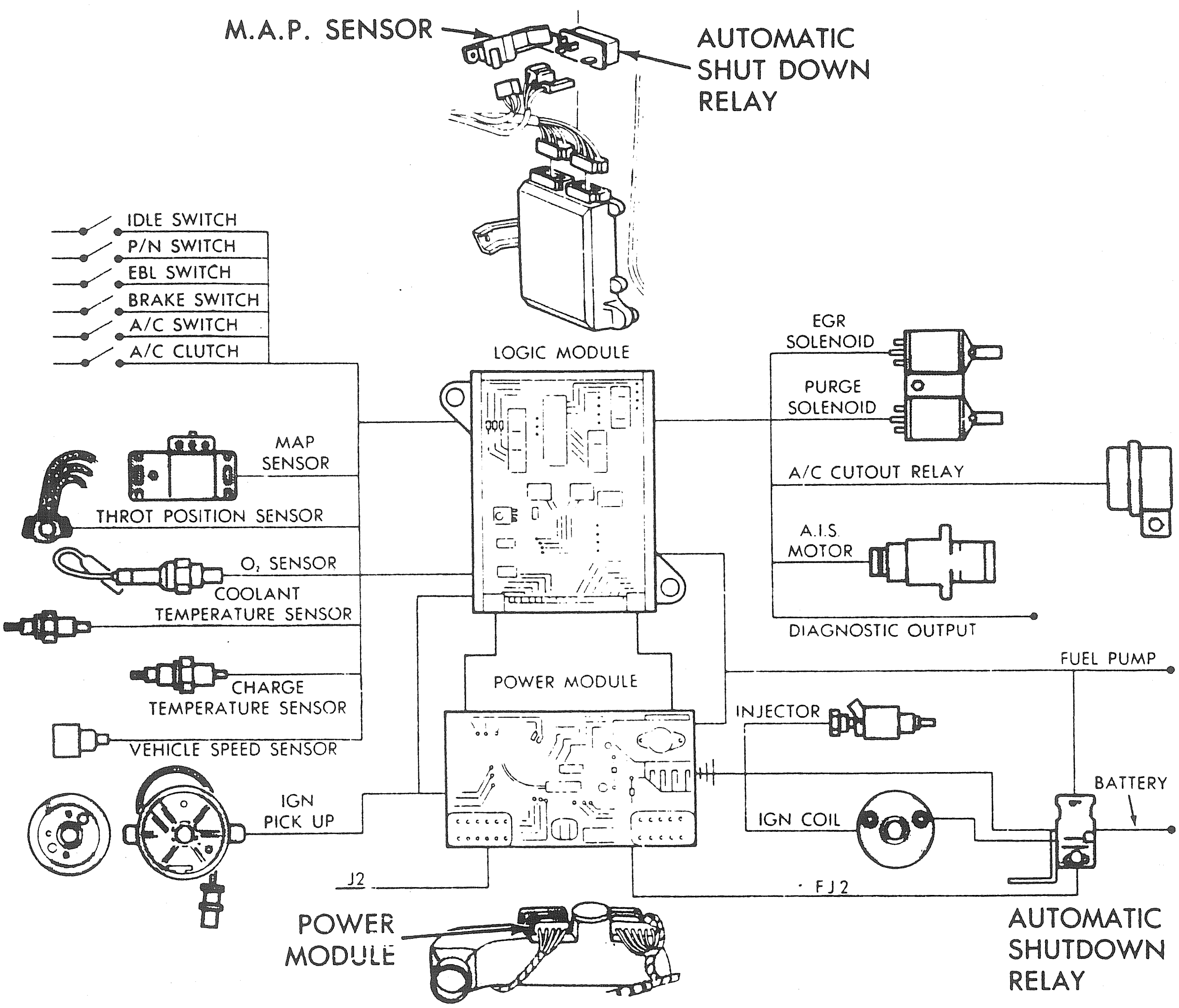


FIGURE 1-12
Typical electronic control system uses various sensors to provide input data to the computer. (Courtesy of Chrysler Motors Corp.)

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. What do engine controls do [1-1]?
2. Briefly describe how electronic controls overcome the problems inherent in mechanical or pneumatic devices [1-4].
3. What is the difference in function between primary and secondary engine controls [1-2]?
4. Where does NO_x originate [1-2]?
5. Explain the drawbacks to mechanical or pneumatic controls [1-4].

REVIEW

1. Electronic processors can handle how many input signals [1-4]?
   a. one
   b. two
   c. three
   d. four or more
2. The carburetor is which type of engine control [1-1]?
   a. primary
   b. secondary
   c. processor
   d. none of these
3. Wear has what effect on a mechanical information processor [1-4]?
   a. may cause it to become inoperative
   b. may throw it out of calibration
   c. both a and b
   d. neither a nor b
4. Secondary controls reduce what factor [1-2]?
   a. fuel economy
   b. emission levels
   c. engine performance
   d. both a and c
5. High CO emissions can be the direct result of [1-2]
   a. a rich air/fuel mixture.
   b. a lean air/fuel mixture.
   c. a leaking vacuum hose.
   d. both b and c.
6. The output signal from a microcomputer goes to a [1-4]
   a. receiver.
   b. sensor.
   c. actuator.
   d. transformer.
7. A signal that comes from an engine sensor to a processor is known as [1-4]
   a. an input signal.
   b. a processor signal.
   c. an output signal.
   d. a sensor voltage.
8. Who monitors the CAFE standards [1-3]?
   a. auto industry
   b. EPA
   c. vehicle manufacturers
   d. both a and c
9. Mechanical processors produce how many output changes [1-4]?
   a. seven
   b. five
   c. three
   d. one
10. NO_x is formed above what engine temperature [1-2]?
    a. 2,000°F
    b. 2,500°F
    c. 3,000°F
    d. 3,500°F

Chapter 2

ELECTRICAL FUNDAMENTALS

OBJECTIVES

After reading and studying this chapter, you will be able to

- explain the basic structure of matter and the atom.
- describe the electron theory of current flow in a conductor.
- explain the differences in current, voltage, and resistance.
- identify and use the various forms of Ohm's law.
- identify the various types of electrical circuits used on motor vehicles.
- describe the effects of magnetism on nonmagnetic and magnetic materials.
- explain how electromagnets are formed.
- describe electromagnetic induction of voltage in a conductor.
- explain the function and design of mechanical, automatic, and electromagnetic switches.
- describe circuit resistors, protection devices, and diagram symbols.

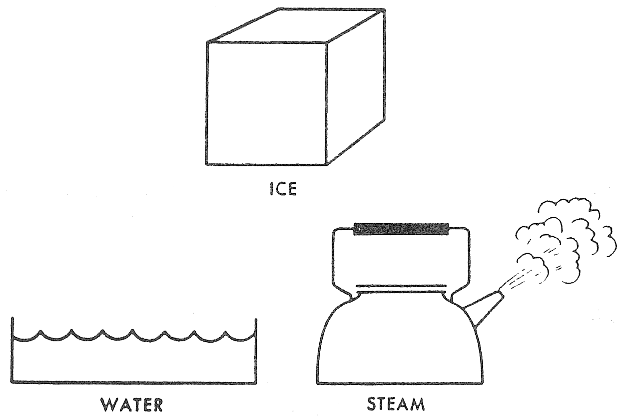


FIGURE 2-1
Three forms of matter: solid, liquid, or gas. (Courtesy of Delco Remy)

The modern automobile incorporates a vast amount of electrical and electronic equipment used to operate the engine, vehicle lighting, and varied accessories. This equipment has become very complex over the years, resulting in many mechanics dropping out of automotive service. As a result, there is a wide gap between technicians who understand electrical fundamentals and those who know very little about the subject.

The point here is that as the automotive industry moves farther away from mechanical or pneumatic controls and closer to using all electrical and electronic units, it becomes more important for all technicians to have a working knowledge of basic electricity. Although Chapter 2 is not a complete course in itself, it does provide the basic theory behind the operation of the electrical equipment found on the automobile. Moreover, the information provided prepares the reader for the more sophisticated electronic data presented in Chapter 3.

2-1 STRUCTURE OF MATTER AND THE ATOM

Although electricity itself is still somewhat of a mystery, its practical use has been known for over 100 years. *Electricity* is an invisible force that behaves according to definite rules and produces predictable results and effects. People have learned how to produce, store, use, and measure electricity, but no one knows exactly what it is. Scientists have a theory, the electron theory, that explains the nature of electricity fairly well. However, it is difficult to understand because electrons cannot be seen or easily illustrated.

Matter

In order to understand what an electron is and how it behaves, let's first briefly examine the composition of matter. *Matter* is anything that has weight and occupies space. For instance, the air that we breathe, the food that we eat, and the chair or sofa on which we sit are all forms of matter—that is, they all have weight (mass) and occupy space.

In addition, matter is not always in the form of a solid; it can be a liquid or a gas (Fig. 2-1). Thus, ice, water, and steam are examples of matter in all three forms. The actual differences in the appearance of forms of matter depend basically on two things: (1) the composition of the molecule, and (2) its physical arrangement within the object itself.

Molecule

A *molecule* is the smallest particle into which matter can be divided but still retain its original physical properties. For example, if a scientist divided a grain of salt in two and then divided each subsequent grain again and again until the division was as fine as possible, the smallest particle still retaining all the properties of salt would be a molecule. This salt molecule would be almost one-millionth of an inch in diameter and would need to be enlarged about 100 times before it could be seen in a microscope.

Molecular Arrangements

As mentioned, science classifies matter by its molecular arrangement into three forms: a solid, liquid, or gas (Fig. 2-2). In a solid form of matter such as a block of ice or a piece of steel, the molecular arrangement is rigid. That is, all molecules are very close to each other and have a strong attraction for one another. This arrangement resists any attempt to change the object's physical shape. For this reason, solid objects are, for practical purposes, not compressible.

In a liquid such as water, the molecular arrangement is not as rigid as the solid material. The molecules in this case do move somewhat in relation to one another or have less attraction for each other. This particular property allows the liquid to conform to its container's shape. Furthermore, the distance between the molecules in a liquid remains relatively close; consequently, it is also not compressible by normal means.

A gas such as steam has molecules that are far apart and move about at high speeds. Moreover, the

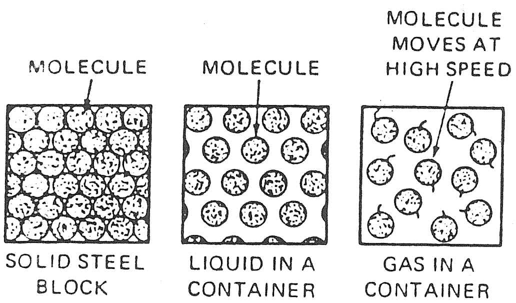


FIGURE 2-2
Molecular arrangement of a solid, liquid, or a gas. The molecule is represented by the circles within the object.

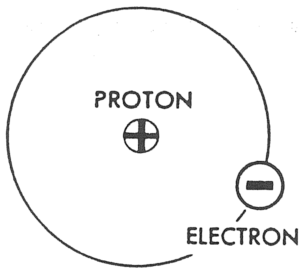


FIGURE 2-3
Hydrogen atom. (Courtesy of Delco Remy)

molecules can move freely in relation to one another and tend to repel each other. These factors give a gas its expansion quality; yet it is compressible by normal means because of the distance between the molecules.

Atoms

Molecules are composed of tiny building blocks called *atoms.* An atom can exist alone or in combination with other atoms to form millions of different forms of matter. An atom that exists alone is known as an *element,* and scientists are aware of over 100 of these atoms or elements on the atomic scale. Hydrogen, copper, and gold are good examples of elements. To signify all these elements, each one has an assigned letter or letters to represent it, such as H for hydrogen and O for oxygen.

In addition, each element differs from the one preceding it on the atomic scale by the addition of one proton and one electron. Hydrogen, for example, is one of the simplest of all atoms; it is number 1 on the atomic scale and has one proton and one electron (Fig. 2-3). Copper, on the other hand, is number 29 with 29 protons and 29 electrons.

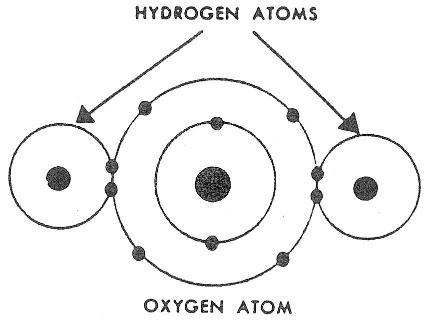


FIGURE 2-4
Atoms combine to form a molecule of water. (Courtesy of Delco Remy)

If two or more atoms combine chemically, they form a molecule (Fig. 2-4). For example, if two atoms of hydrogen (H2) combine with one atom of oxygen (O), they form water (H_2O). Both kinds of atoms are gases, but they form a liquid when combined under proper conditions.

Structure of the Atom

According to the electron theory, the atom itself is further divisible into even smaller particles known as *protons, neutrons,* and *electrons* (Fig. 2-5). These particles are the same within different atoms, and the different properties of matter such as hardness, softness, toughness, fragility, conductivity, or nonconductivity occur because of the number and arrangement of these particular particles.

Both protons and electrons have a type of electrical charge—the proton, positive (+), and the electron, negative (−). The neutron has no electrical charge but adds weight to the atom.

The particles also have a definite placement within the atom. The protons and neutrons are tightly bound together to form the center or nucleus of the atom, much as the sun does in our solar sys-

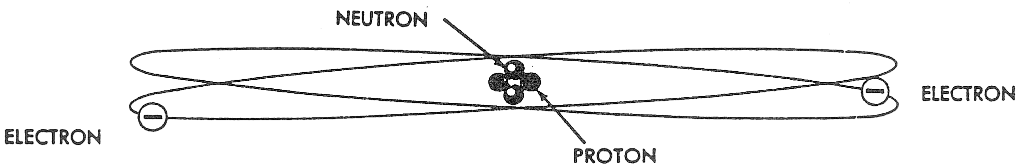


FIGURE 2-5
Structure of the atom. (Courtesy of Delco Remy)

tem (Fig. 2-6). The electrons, on the other hand, turn in one or more orbits around the nucleus, much as the Earth, Venus, Mars, and other planets rotate around the sun. The electrons are held in their orbits by the positive-charged nucleus. Moreover, if electrons approach each other, they are repelled because of the similar charge, while still maintaining their orbital position around the nucleus.

This interaction between the electrons and the nucleus or between the electrons themselves is the result of basic laws of electricity. These laws are

1. Unlike charges attract one another.
2. Like charges repel one another.

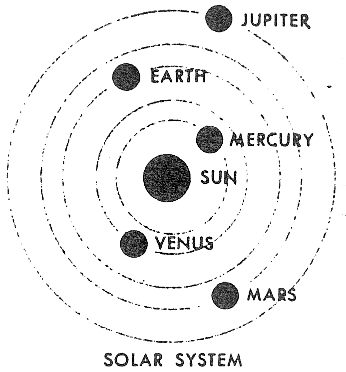


FIGURE 2-6
Solar system. (Courtesy of Delco Remy)

2-2 ELECTRON THEORY

The *electron theory* states that a flow of electricity, or current flow, is the movement of electrons between atoms within a conductor. To understand this statement, it is first necessary to explain the differences between a good conductor and an insulator, or nonconductor.

Conductors

For purposes of explanation, let us examine the makeup of a good electrical conductor, the copper atom (Fig. 2-7). Within this atom are four orbital paths for the electrons. In the innermost orbit, closest to the nucleus, are 2 electrons. The second orbit contains 8, while the third orbit has 18. The electrons in these three orbits are known as *bound electrons* because they are held tightly in their respective positions by the unlike charge of the protons within the nucleus.

The fourth orbit has only 1 electron, which is commonly known as a *free electron* because it can become dislodged from its orbit rather easily (Fig. 2-8). Since this electron is further from the nucleus, its negative attraction to the positive-charged nucleus is reduced.

If a copper atom loses an electron, it takes on a more positive charge because it has more protons (29) than electrons (28). Before the electron was lost, the atom was electrically in balance, having the same number of protons and electrons.

In any conductor with free electrons, the atoms are usually so close together that their orbits overlap. *Electron drift* occurs when an electron dislodges from one atom in a conductor and moves to an outer orbit of another. As long as the conductor is not connected into a live electrical circuit, the pattern of electron movement remains random. If an atom in one place loses an electron, another one, from somewhere else, takes its place. This is due to the extra positive charge exerted by the atom that has lost its electron. Finally, since the movements are random, the total of all the electrical charges of all the atoms in the conductor remains in balance.

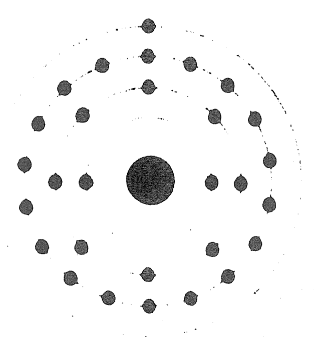


FIGURE 2-7
Structure of the copper atom. (Courtesy of Delco Remy)

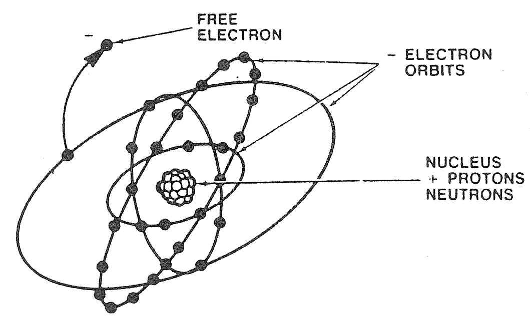


FIGURE 2-8
Free electron of a copper atom dislodged from its orbit. (Courtesy of Chrysler Motors Corp.)

Current Flow

If the free electrons are somehow organized to drift in one direction, the result is called an *electric current* or *current flow.* In order to have this organized current flow, something must force the free electrons from their orbits. Friction, heat, magnetism, or chemical activity are all examples of forces that can expel electrons from their orbital paths.

In the automotive electrical system, current flow is due to the action of the battery or alternator. These devices produce *electromotive force* (EMF), which literally means electron moving force, or the difference in electrical pressure that causes the electrons to flow from atom to atom in a given direction within the conductor.

For the present, we will use the battery as the device that causes electron flow in the conductor. The battery itself has two terminals, one positive and one negative. The positive terminal, through chemical action, has a net *positive charge,* or an abundance of protons. The negative terminal, on the other hand, has an excess of electrons or a *negative charge* (Fig. 2-9). Simply speaking, the battery chemically produces an electrical imbalance or a difference in pressure (EMF).

If you connect a copper wire, which contains billions of atoms per square inch, between the two terminals of a battery, electrons will flow from negative to positive. Figure 2-9 shows this action within the copper conductor. Although this conductor contains billions of copper atoms, all having free electrons, the diagram only shows a few atoms and the movement of negative charges between them.

The electron closest to the positive terminal of the battery is drawn out of orbit and passes into the net positive charge of the battery. Remember, unlike charges attract one another.

This atom, therefore, now has a net positive charge because it has one less electron. As a result, the atom attracts an electron from an adjacent atom. This action, in turn, attracts an electron from the next atom and so forth.

In addition, at the opposite end of the conductor, the negative battery terminal applies a push on the electron in the first atom because like electrical charges repel each other. The result of both the attracting and repelling actions is the forced movement of the electrons through the wire from the negative end toward the positive side.

This flow of current continues as long as the unlike positive and negative charges remain at the two terminals of the battery and there is an uninterrupted path, or circuit, between the two. However, when there is neither an excess of electrons at the negative terminal nor an excess of protons at the positive, a balance of electrical charges exists, and electron flow will cease.

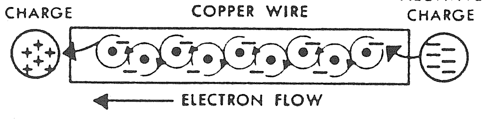


FIGURE 2-9
Flow of electrons in a copper conductor placed between two battery terminals. (Courtesy of Delco Remy)

Nonconductors

A *nonconductor,* or *insulator* (like rubber, wood, bakelite, and porcelain), is said to have bound electrons. These substances have five or more electrons in their outer orbits, that cannot be easily dislodged from their respective positions. Consequently, these materials cannot normally carry a current of electricity. In other words, they have high anti-electric properties, or *dielectric strength.*

2-3 ELECTRICAL CURRENT, VOLTAGE, AND RESISTANCE

When discussing electricity, there are three basic factors: current, voltage, and resistance. These terms are basic to the understanding of electricity and its effects within the complex electrical and electronic systems of the automobile.

Current

As mentioned, the flow of electrons in a conductor is known as a current of electricity. The measurement for current flow is in *amperes* (A). One ampere is an electric current of 6.24 billion, billion electrons (6.24×10^{18} electrons) passing a given point in a conductor in 1 second (Fig. 2-10). A smaller unit of current flow is the *milliampere* (mA), which is $\frac{1}{1{,}000}$ of

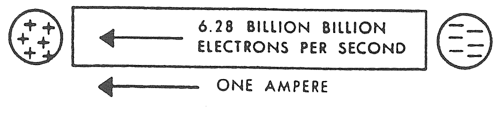


FIGURE 2-10
Measurement of current flow. (Courtesy of Delco Remy)

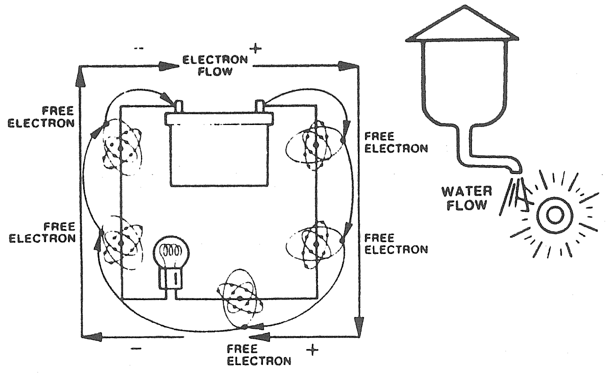


FIGURE 2-11
Electrical current compared to water flow. (Courtesy of Chrysler Motors Corp.)

an ampere. Thus, current is the rate of electron flow and is measurable in amperes or electrons per second. It is this current flow through a conductor that performs the work of operating the electrical units in the automobile—for example, the starter motor, headlights, and the ignition system.

When electrons flow along a conductor to an electrical unit, their effect on it is instantaneous. Although the electrons themselves do not travel more than a few inches a second, the electrical energy applied to one end of a circuit is transmitted to the unit on the other end at the speed of light (186,000 miles per second).

Current is comparable to the flow of water in a pipe. In fact, comparing current to water flow is undoubtedly the easiest and quickest way to explain this and all factors dealing with electricity. Current flow is the movement of electrons through a conductor (wire) just as water flow is the movement of liquid through a pipe (Fig. 2-11). As mentioned, an ampere is the electrical measure for current flow, while gallons per minute is the measurement for the rate of water moving through a pipe.

Voltage

Another term more commonly used to represent EMF, or electrical pressure, is *voltage*. Electrical pressure is measured in volts and is what frees the electrons to create current flow within a conductor.

The amount of voltage depends on the difference in electrical charges, either positive or negative, existing at each end of the conductor (Fig. 2-12). The greater the charges are at each point, the higher the voltage. In other words, the greater the lack of electrons at the positive terminal and the greater the excess of electrons at the negative terminal, the higher the voltage will be.

FIGURE 2-12
Voltage exists between two unlike electrical charges. (Courtesy of Delco Remy)

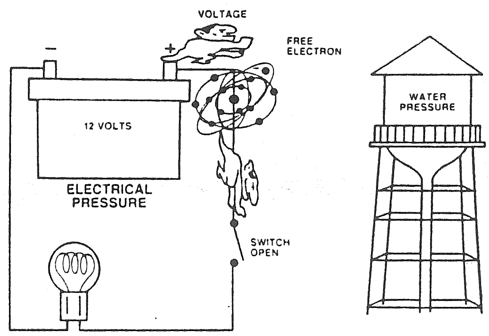


FIGURE 2-13
Both a battery and a water tower provide pressure. (Courtesy of Chrysler Motors Corp.)

Voltage is a potential force and can exist even when there is no current flow within a circuit. The vehicle battery, for example, may have a potential of 12.6 volts between its positive and negative terminals. This pressure is there even if there are no current-consuming devices connected across its terminals. Consequently, voltage can exist without current flow, but current flow cannot occur without the push of voltage.

In one regard, the battery and a water tower have something in common in that they both provide pressure (Fig. 2-13). The battery is a source of electrical pressure due to its internal chemical action; the tower provides water pressure due to the action of gravity on the weight of the liquid in the tank. In other words, battery voltage is simply electrical pressure. It is this potential that pushes the electrons through the wire in a complete circuit, just as the pressure at the outlet of the tower forces the water through the pipes in a plumbing system.

Resistance

Electrical resistance is opposition to the flow of electrons, and all electrical conductors offer some resistance (Fig. 2-14). Basically, resistance is the result of each atom resisting the removal of an electron due to the electron's attraction to the nucleus, and due to collisions of countless electrons as they move through the conductor. These collisions cause resistance and create heat in the conductor itself.

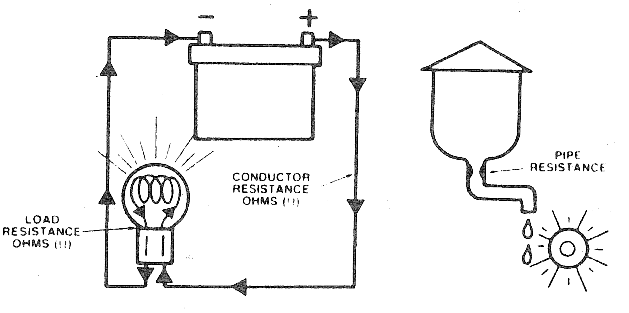
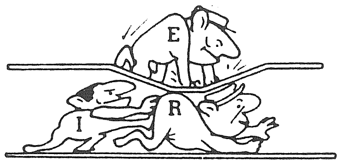


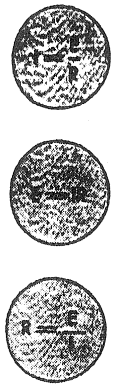
FIGURE 2-14
Resistance reduces current flow. (Courtesy of Chrysler Motors Corp.)



OHM'S LAW: $\frac{E}{I \times R}$

E = IR (VOLTAGE = AMPERAGE TIMES RESISTANCE)
I = E ÷ R (AMPERES = VOLTAGE DIVIDED BY RESISTANCE)
R = E ÷ I (RESISTANCE = VOLTAGE DIVIDED BY AMPERES)

FIGURE 2-15
Ohm's law defines electrical behavior. (Courtesy of Chrysler Motors Corp.)



$$\text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$$

$$\text{VOLTS} = \text{AMPERES X OHMS}$$

$$\text{OHMS} = \frac{\text{VOLTS}}{\text{AMPERES}}$$

FIGURE 2-16
Three equations derived from Ohm's law. (Courtesy of Delco Remy)

Several other factors increase or decrease resistance. For instance, the size of the wire also affects resistance. A small wire causes more resistance to current flow than a larger one of the same material, in much the same way a small pipe in a water system offers more opposition to liquid flow than a large pipe.

In addition, the length of the wire and the material from which the manufacturer makes it affect resistance. A shorter wire offers less resistance than a long one, and good conductor material provides less resistance than poor conductor material. Manufacturers use metals like copper, aluminum, and silver for conductors because they offer low resistance.

Resistance, therefore, is the only real difference between good conductors and good insulators. Any material that is an extremely poor conductor is usually a good insulator. In other words, an insulator is a material that offers enough resistance to prevent the flow of current.

The basic unit of measurement for resistance is the *ohm* (Ω). One ohm is the resistance that will only allow one ampere to flow in a circuit with a pressure of one volt.

2-4 OHM'S LAW

In the early 1800s, the scientist George S. Ohm formulated a law that links voltage, current flow, and resistance within a basic electrical circuit (Fig. 2-15). Ohm found that the current in a circuit is directly proportional to the applied voltage and inversely proportional to the resistance in the circuit. In simpler form,

1. When resistance goes up or down, current flow decreases or increases, assuming the voltage remains the same.

2. When voltage goes up or down, current flow increases or decreases, assuming the resistance stays the same.

3. When resistance goes up, current flow decreases, assuming voltage remains the same.

4. When resistance goes down, current flow increases, assuming voltage remains the same.

Ohm's law can be expressed as an equation showing the relationship among current flow (I), voltage (E), and resistance (R). The equation is E = I × R, or voltage equals amperage times resistance. This simply means that one volt will push one ampere of current through one ohm of resistance.

Since Ohm's law is an equation, you can write it three different ways. Consequently, if you know two factors about a circuit, you can calculate the third or unknown by using one of the following equations (Fig. 2-16):

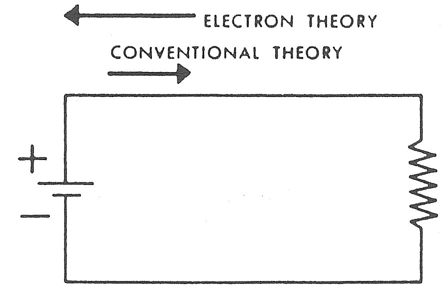


FIGURE 2-17
Two theories of current flow in a circuit. (Courtesy of Delco Remy)

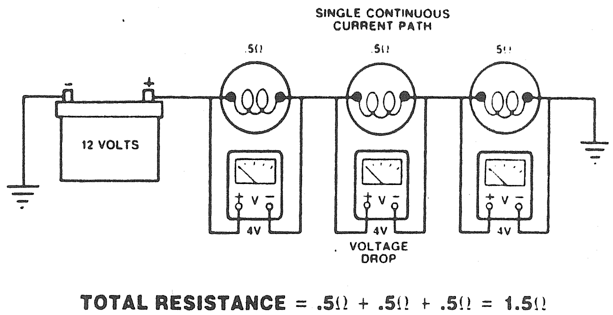


FIGURE 2-18
In a series circuit, there is only one path for current flow. (Courtesy of Chrysler Motors Corp.)

1. Amperes equal volts divided by ohms.
2. Volts equal amperes times ohms.
3. Ohms equal volts divided by amperes.

To use the equations, simply substitute the values in amperes, volts, or ohms, and solve for the missing value.

2-5 ELECTRICAL CIRCUITS

As mentioned, batteries and alternators apply electrical pressure and cause current to flow through a circuit from the high-pressure side to the low-pressure side, or from negative to positive. However, there must be a complete *circuit* or pathway (made up of wires or other conductors) in order for the current to flow. If for some reason a wire is broken or disconnected, it loses its completeness, or *continuity,* and current flow stops abruptly.

Automotive circuits are not all alike, and electricity does not behave exactly the same in the different types of circuits. Therefore, it is important that the technician understand the basic types of circuits, and how volts, amperes, and ohms behave in each one.

Simple Circuit

The easiest way to explain the basic circuits is through the use of a battery (the power source), some wire (the conductor), and one or more electrical lamps or other devices that serve as resistance units. In the *simple circuit,* current flows from the battery, through the lamp or resistor, and back to the battery via the conductor (Fig. 2-17).

However, most automotive circuits have more than one lamp or resistance unit and use the vehicle body and frame as the circuit from the resistance unit to the negative side of the battery. This forms a single-wire circuit.

There are two ways to describe current flow in any circuit, using either the conventional theory or the electron theory (see Fig. 2-17). In the conventional theory, current flows from the (+) terminal of the battery, through the circuit, to the (−) terminal of the battery. The electron theory states that current flow is from the (−) terminal of the battery, through the circuit, to the (+) terminal of the battery.

Either theory is usable. *This text utilizes the conventional theory in its remaining explanation of electrical circuits and devices because it is more popular and easier to use on automotive single-wire circuitry.*

Series Circuit

In a *series circuit,* two or more lamps or resistance units connect in such a way that there is only one continuous path for current flow (Fig. 2-18). Since within a series circuit all the current must flow through each resistance unit, the current flow is always the same everywhere. This is always true regardless of the number of resistance units connected in series into the circuit.

There are four important things to remember about the series circuits. First, there is only one path for current to flow. Second, the sum of all voltage drops in the circuit is equal to battery voltage. Third, the total resistance in a series circuit is equal to the sum of all the resistances. Finally, an opening in any part of a series circuit, or resistance device, stops the current flow throughout the entire circuit.

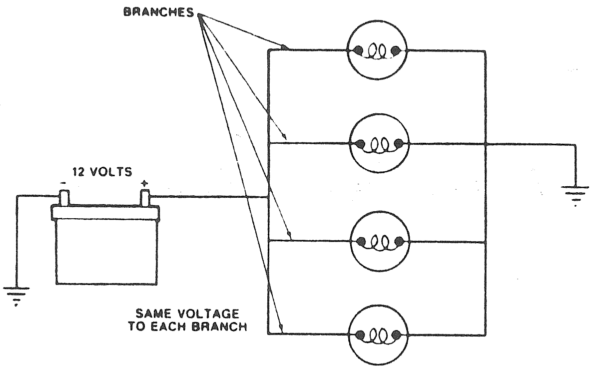


FIGURE 2-19
Parallel circuit provides several paths for current flow. (Courtesy of Chrysler Motors Corp.)

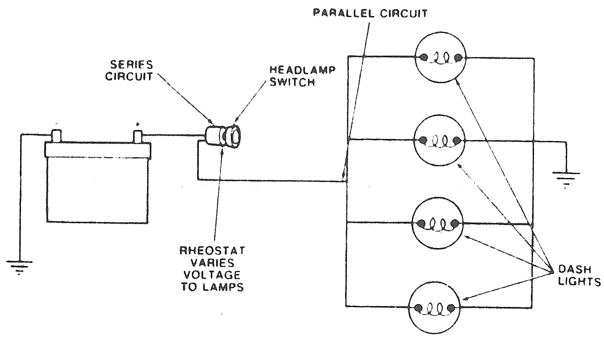


FIGURE 2-20
Typical series-parallel circuit. (Courtesy of Chrysler Motors Corp.)

Parallel Circuit

In a *parallel circuit,* the lamps or resistance units connect in such a way that there is more than one path for current flow (Fig. 2-19). This simply means that part of the current flows through one lamp and part of it moves through the other resistance units. Should any of the paths become open, current will still continue to flow through the other branches and operate the resistance units.

Also in this type of circuit, the voltage drop across each resistor is equal to the voltage of the battery since there is a separate path for current to flow through each lamp. This means that the voltage across each resistance unit is the same.

If any of the resistance values in a branch is different, current through each lamp is not the same. Current always flows through the path of least resistance. Finally, the total current flow in the parallel circuit is equal to the sum of all the currents flowing in each of its branches.

The total resistance in a parallel circuit is always less than that of the smallest resistance unit in the circuit. This is explained by the fact that there is less resistance to current flow when a number of branches are in a circuit to provide for electron movement than when only one path is available.

Series-Parallel Circuits

The automobile has many series-parallel circuits. In a *series-parallel circuit,* the resistance of a lamp, load device, rheostat, or switch is in series between the battery and the branches of the parallel circuit. This has the effect, in most cases, of dropping the voltage to the lamps in the parallel paths.

Figure 2-20 illustrates a typical series-parallel circuit. Notice in the drawing that the headlamp switch can open or close the circuit to the lamps and also change the resistance in the series portion. In other words, the switch can control current flow, or the rheostat can vary the voltage to the parallel circuit branches.

An opening in the series portion of the circuit will stop all current flow. However, an opening in one of the parallel branches will stop current flow along the affected pathway but not in the total circuit.

Open Circuit

There are two other types of electrical circuits, open and short. An *open circuit* indicates a break or loss of continuity somewhere within the circuit so that there is no longer a complete or continuous path for the current to flow through.

The opening may be the result of a break in a wire, loose connection, defective switch, defective resistance unit, or no ground. Moreover, the opening can be located on either side of a resistance unit. An opening in a series circuit stops current through the entire circuit (Fig. 2-21).

The effect of an opening in a parallel circuit depends on the location of the break. If the break is in the circuit feed or control switch (series portion of the circuit), current flow stops in all the branches.

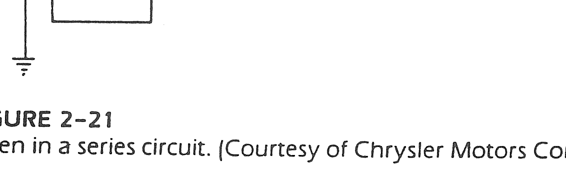


FIGURE 2-21
Open in a series circuit. (Courtesy of Chrysler Motors Corp.)

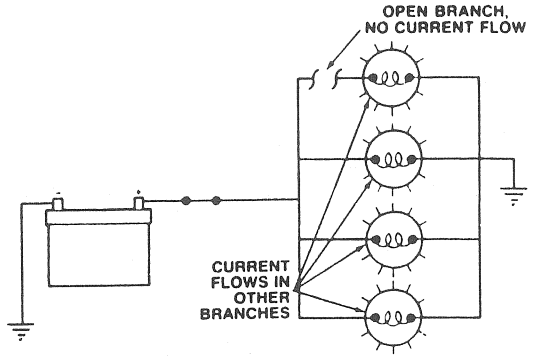


FIGURE 2-22
Open in a parallel circuit. (Courtesy of Chrysler Motors Corp.)

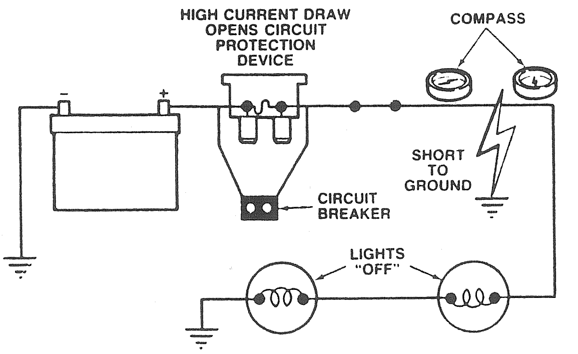


FIGURE 2-23
Typical short circuit to ground. (Courtesy of Chrysler Motors Corp.)

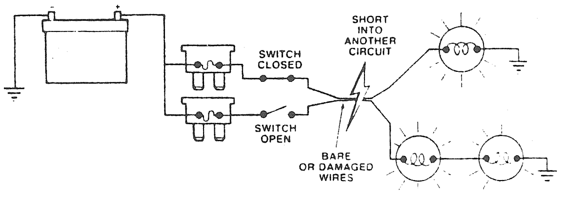


FIGURE 2-24
Short into another circuit. (Courtesy of Chrysler Motors Corp.)

However, an opening in an individual branch only stops the current flow along the affected path. The current flow in the other branches will not be affected by the opening (Fig. 2-22).

Short Circuit

A *short circuit* is a continuous path for current flow that interrupts or bypasses its intended course through the circuit. One type of short is directly to ground, while others may be into another circuit (Fig. 2-23).

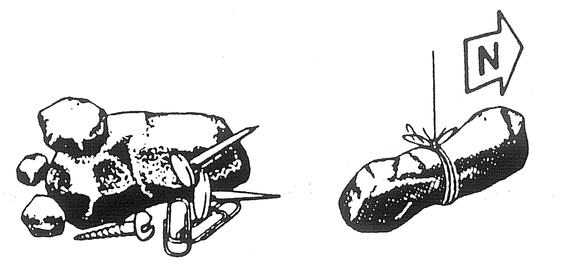


FIGURE 2-25
Magnetic effects of lodestone. (Courtesy of Delco Remy)

With a *short to ground,* the current bypasses the resistance unit. This reduces the total resistance in the circuit and causes a large amount of current flow. As a result, a fuse blows, circuit breaker cycles open and close, or the fusible link opens.

A *short into another circuit* usually results from two bare wires touching or from a damaged wiring harness (Fig. 2-24). Often this situation creates an additional branch of a parallel circuit. Since current always follows the path of least resistance, the majority of the current flows in the branch with the smallest amount.

Moreover, a switch closed in one circuit energizes other circuits that should at the moment be deactivated. If the circuit with the closed switch is a series type circuit, it now becomes parallel. Since the parallel circuit has less resistance than the series, additional current flows, which may open the circuit protection device.

2-6 MAGNETISM

The principle of magnetism became the basis for the navigation compass over 1,200 years ago. The discovery of the effects of magnetism was the result of observing how fragments of iron ore called lodestone attracted other pieces of iron (Fig. 2-25). It was also noticed that a long piece of this particular ore, if suspended in air with a string, would align itself so that one end always pointed to the North Pole of the earth. Therefore, this end of the lodestone became known as its north (N) pole, and the opposite end as the south (S) pole.

Magnetic Fields

Further study of the bar magnet showed the existence of an invisible attractive force that exerted itself on bits of iron or iron filings even though they were some distance away. Although mysterious,

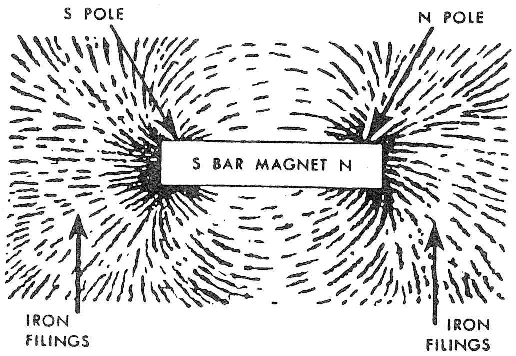


FIGURE 2-26
Effects of the magnetic field around a bar magnet. (Courtesy of Delco Remy)

this phenomenon makes it very clear that some form of force exists in the space close to the magnet.

The force that fills this space around the magnet and into which iron filings attract is known as a *magnetic field.* The field is nothing more than invisible lines of force that come out of the N pole and enter the S pole (Fig. 2-26).

You can see the effects of these magnetic lines of force by sprinkling iron filings on a piece of paper resting on top of a bar magnet. If you lightly tap the paper by hand, the iron filings line up to form a clear pattern around the bar magnet. The pattern also shows that these lines of force heavily concentrate themselves at the N and S poles of the magnet and then spread themselves out into the surrounding air between the poles. The concentration or the number of lines at each pole is equal, and the attractive force on the filings at each pole is the same (see Fig. 2-26).

Fundamental Law of Magnetism

There is a fundamental law that deals with magnetism. This law states that *unlike poles attract one another, and like poles repel each other.*

Figure 2-27 demonstrates this fundamental law. In the upper portion of the illustration are two magnets placed so that the N pole of one and the S pole of another are close together. In this situation, the magnetic lines of force leaving the N pole of the right-hand magnet enter the S pole of the left-hand one, creating an attractive force since all lines of force are in the same direction. As a result, the adjacent N and S poles do attract each other, and the attractive force increases as the two magnets move closer together.

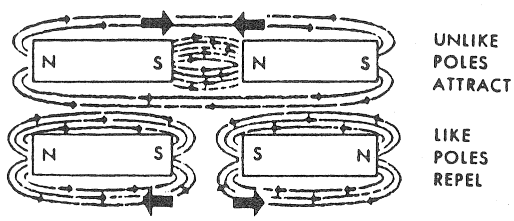


FIGURE 2-27
Fundamental law of magnetism. (Courtesy of Delco Remy)

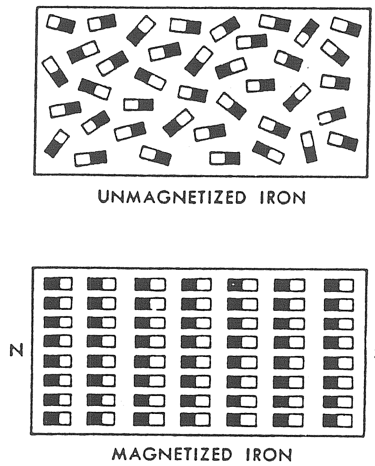


FIGURE 2-28
In a natural magnet, the molecules are in alignment. (Courtesy of Delco Remy)

The lower diagram shows two magnets lying end-to-end with both their S poles adjacent to one another. In this instance, the lines of force from both magnets move in opposite directions. As a result, the adjacent poles repel one another.

Note: In understanding this magnetic principle, it is helpful to know a rule that says that lines of force never cross one another. While this statement is not theoretically correct, it has often been found effective in explaining this phenomenon.

Theory of Magnetism

Although no one knows exactly what magnetism is, there is a theory that tries to explain what it is and how it exerts a force field. The theory implies that a magnet, like all matter, is formed of molecules. The molecules in a magnet are lined up in such a way as to make their electrostatic fields work together in one direction (Fig. 2-28). When a material has no magnetic properties, the molecules are thought to be arranged in a random manner.

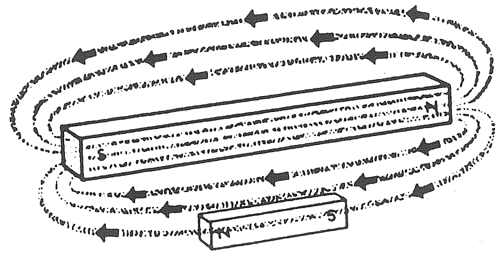


FIGURE 2-29
Inducing magnetism into an iron bar. (Courtesy of Delco Remy)

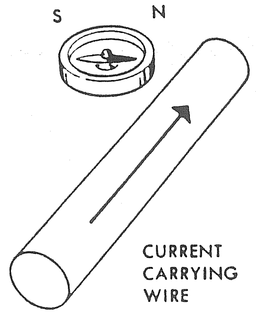


FIGURE 2-30
Compass shows the magnetic field to be at a right angle to the conductor. (Courtesy of Delco Remy)

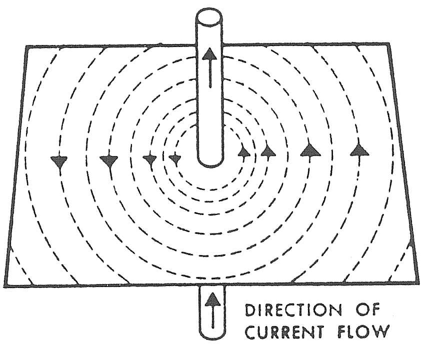


FIGURE 2-31
Shape of the magnetic field around a current-carrying wire. (Courtesy of Delco Remy)

Magnetic and Nonmagnetic Materials

Iron is one of the better-known magnetic materials. However, most permanent magnets are manufactured from alloys because softer metals do not retain magnetism for very long. A few of the most common alloys are nickel-iron and aluminum-nickel-cobalt.

A number of materials are nonmagnetic because they do not exhibit any magnetic properties. A few of these nonmagnetic materials are wood, paper, glass, copper, and zinc.

Formation of a Magnet

You can convert an iron bar into a magnet in a number of ways. One method, for example, is to stroke the iron bar with a magnet. Since the molecules within the magnet are in alignment, the pull of unlike poles and the push of like poles align the molecules in the iron bar. Producing a magnet in this way is known as magnetic induction.

A second method also uses magnetic induction. However, this time the iron bar is positioned in a strong magnetic field (Fig. 2-29). The lines of force from the magnet itself pass through the iron bar; this action aligns the molecules in the bar. As a result, the iron bar becomes a magnet as long as it remains in the magnetic field. If you remove the field of force and the bar's composition is such that it retains some of the induced magnetism, it becomes a permanent magnet.

2-7 ELECTROMAGNETISM

A magnetic field always exists around a current-carrying conductor. Such a field of force is always at right angles to the conductor (Fig. 2-30). If you hold a compass over a wire, for instance, the needle turns so that it is crosswise (at a right angle) to the wire. Since the only thing that attracts the compass needle is a magnetic field, it is obvious that the current flowing in the wire created a force field around itself. This reveals the connection between magnetism and electricity.

You can observe the nature of the magnetic field around the conductor by positioning a piece of cardboard over the wire, as shown in Fig. 2-31, and then sprinkling iron filings on the cardboard. The iron filings align themselves to indicate a clear pattern of concentric lines around the conductor. In addition, the circles appear more concentrated near the wire than further out. Finally, although the iron filings on the cardboard piece only show the pattern in one plane, remember that the concentric lines of force extend over the entire length of the current-carrying conductor.

Magnetic lines have a certain direction and change this direction whenever the current flow in the conductor reverses itself (Fig. 2-32). When the current flow is away from the reader, the N pole of the compass needle points in the direction shown in the upper illustration. On the other hand, when current in the wire flows in the opposite direction (toward the reader), the N pole of the compass re-

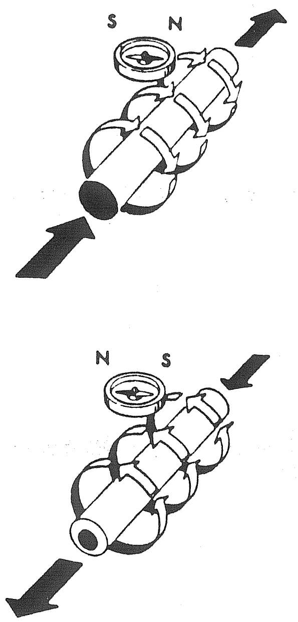


FIGURE 2-32
Whenever the current flow reverses in a conductor, the magnetic lines change direction. (Courtesy of Delco Remy)

verses and points in the opposite direction. This action results because the compass needle always has a tendency to align itself so that the magnetic lines from the conductor enter its S pole and leave the N pole.

You can determine the actual direction by which the magnetic field encircles a wire by using the right-hand rule (Fig. 2-33). With the right hand, grip the wire so that the thumb extends in the direction of current flow. As shown in the illustration, your fingers will encircle the conductor in the direction of the magnetic field.

Note: The use of the right-hand rule, in this case, is necessary if you are using the conventional theory of current flow.

Force Strength

As the current through the conductor increases, the number of lines of force (strength of the magnetism) grows (Fig. 2-34). If (as shown in the upper illustration) you move the compass a distance away from the wire, the compass needle reaches a place where it is no longer affected by the conductor's magnetic field. If you then increase the current flow through the conductor (note the lower illustration) without moving the compass, its needle responds to indicate the presence of an increased magnetic field. This action indicates that the number of lines of force in the

FIGURE 2-33
The right-hand rule can be used to determine the direction of the lines of force around a wire. (Courtesy of Delco Remy)

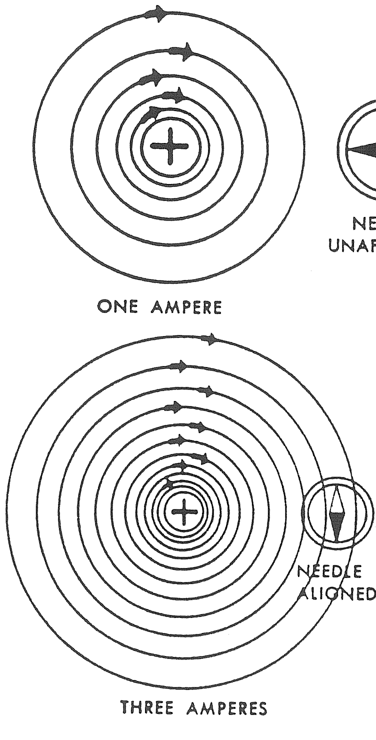


FIGURE 2-34
An increase in current flow within the wire creates a stronger magnetic field. (Courtesy of Delco Remy)

area around the wire grows as current through the wire increases. In other words, additional current flow creates a stronger magnetic field around the conductor.

When two adjacent, parallel conductors carry current flow in opposite directions, the movement of the magnetic field is clockwise around one wire and counterclockwise around the other (Fig. 2-35). In this situation, the lines of force concentrate themselves between the two conductors and spread out

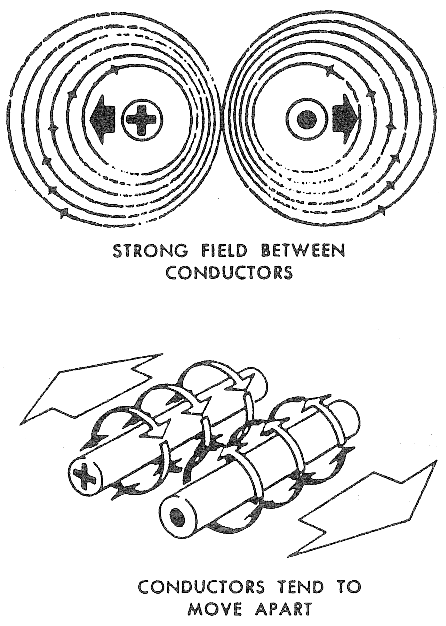


FIGURE 2–35
A current-carrying conductor moves from a strong to a weak magnetic field. (Courtesy of Delco Remy)

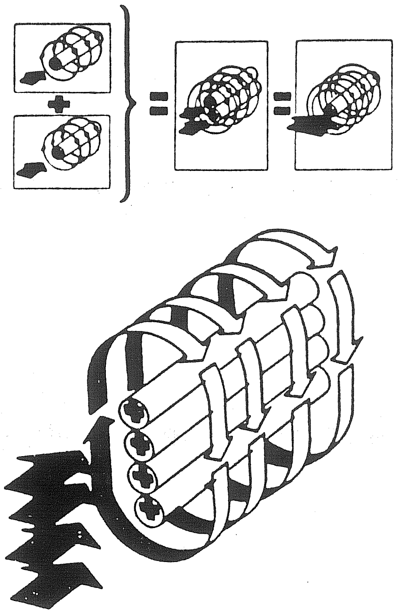


FIGURE 2–37
Two or more adjacent wires with the same current flow increase the magnetic field. (Courtesy of Delco Remy)

into space on the outside of them.

The lines of force between the two conductors move in the same direction; this forms a concentration of lines or a strong magnetic field. Under these conditions, the two wires tend to move apart. In other words, a current-carrying conductor tends to move out of a strong field into a weak one.

However, a different situation exists when two parallel conductors carry equal current flow in the same direction (Fig. 2–36). In this case, a magnetic field, clockwise in direction, forms around each wire with the magnetic lines between them opposing each other in direction. As a result, the magnetic field between the conductors cancels out, leaving essentially no field in this area. This causes the two wires to move toward each other, that is, from a strong field to a weak one.

As mentioned, the magnetic field around a current-carrying conductor grows in intensity as current flow through it increases. However, there is another way of achieving the same result. For instance, two wires lying alongside each other, each carrying current in the same direction, create a magnetic field equivalent to one conductor carrying twice the current flow (Fig. 2–37). The reason for this is that when several more conductors are side-by-side, the magnetic effect increases as the lines from each wire join around all of them.

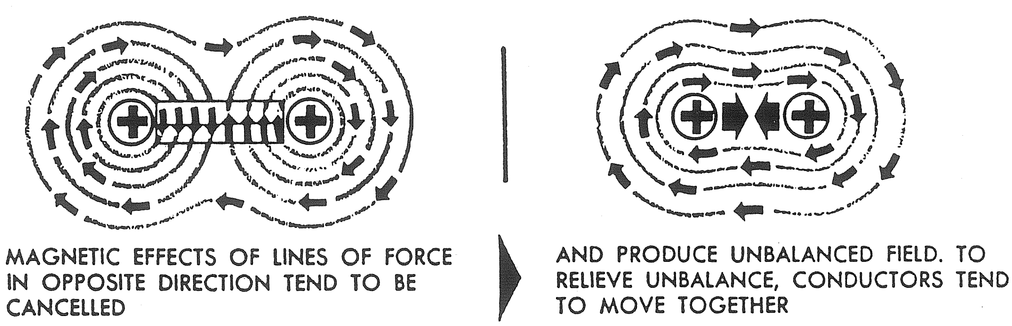


FIGURE 2–36
If their current flow is in the same direction, adjacent conductors tend to move together. (Courtesy of Delco Remy)

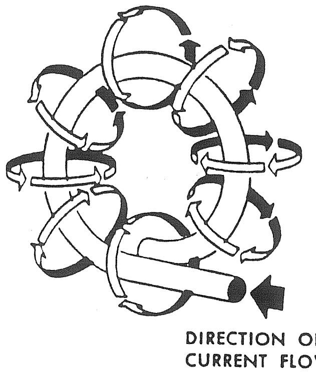


FIGURE 2-38
When a loop of wire carrys current flow, the lines of force concentrate inside the coil. (Courtesy of Delco Remy)

Electromagnetism in Coils

When you form a straight, current-carrying wire into a single loop (Fig. 2-38), it has the same magnetic field surrounding it as when it is straight. But in this instance, all the lines of force enter the inside loop of the wire on one side and leave from the other side. These lines of force, therefore, concentrate themselves inside the loop. Consequently, this single loop of wire forms a basic electromagnet that has polarity.

When the current-carrying wire is wound into a number of loops or turns to construct a coil (Fig. 2-39), the resulting magnetic field is the sum of all the single loop fields added together. This has the same effect as several conductors, side-by-side, carrying current in the same direction.

Moreover, with the lines of force leaving the coil at one end and entering it at the other, a N and S pole form at the ends as in the bar magnet. If the coil is wound over a material such as iron, the assembly becomes a useful electromagnet.

The addition of this iron core greatly increases the strength of the magnetic field at the N and S poles (Fig. 2-40). The reason for this is that air is a very poor conductor of magnetic lines, while iron is a very good conductor. Relatively speaking, the use of iron in the coil's core increases the magnetic strength by about 2,500 times over a coil with an air core.

The strength of the magnetic poles within the electromagnet is directly proportional to its current flow and the number of turns of wire (Fig. 2-41). For example, both an electromagnet having one ampere flowing through its 1,000 turns of wire and another one having 10 amperes flowing through 100 turns have 1,000 ampere-turns, which is a measurement of their magnetic-field strength. In other words, the attraction of other magnetic materials placed within the fields of both these coils is the same.

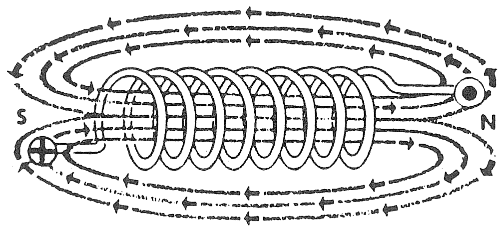


FIGURE 2-39
The magnetic field of a coil grows by increasing the number of loops or turns. (Courtesy of Delco Remy)

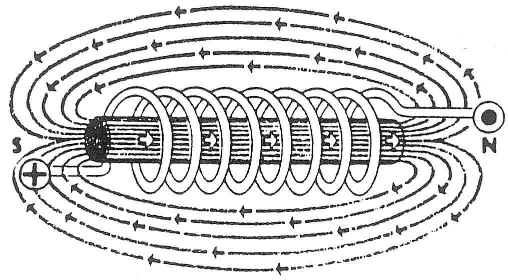


FIGURE 2-40
Using an iron core increases the field strength of the coil. (Courtesy of Delco Remy)

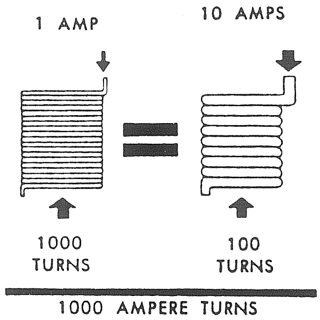


FIGURE 2-41
The total strength of an electromagnet depends on the current flow and the number of coil turns. (Courtesy of Delco Remy)

Electromagnetic Induction

When any conductor moves through a magnetic field, its lines of force induce a voltage into the wire. This basic principle is known as *electromagnetic induction.* Figure 2-42 shows this point very well. When the straight wire moves across (cuts through) the magnetic field of the horseshoe magnet, the attached sensitive voltmeter registers a small induced voltage.

However, if the conductor moves parallel with

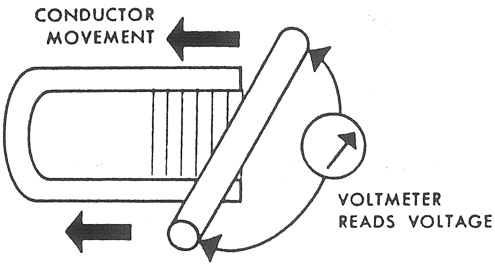


FIGURE 2-42
Moving a conductor through a magnetic field induces a voltage into the wire. (Courtesy of Delco Remy)

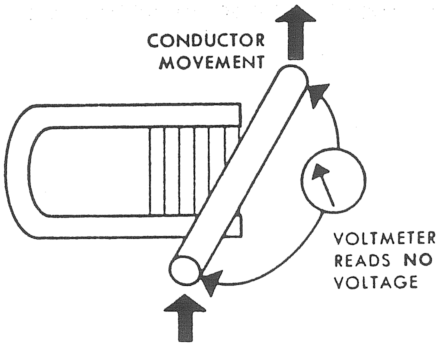


FIGURE 2-43
Moving the wire parallel to the field induces no voltage in the conductor. (Courtesy of Delco Remy)

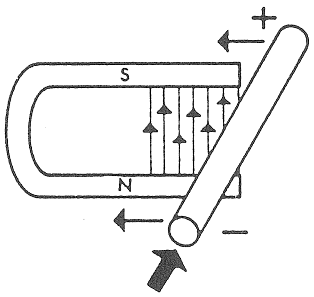


FIGURE 2-44
Voltage polarity of the conductor as it moves through the magnetic field. (Courtesy of Delco Remy)

the lines of force, it cannot induce a voltage in the wire (Fig. 2-43). In other words, the wire must cut across the lines of force in order for the field to induce voltage in it.

As mentioned, voltage (EMF) has polarity; that is, it has (+) and (−) poles. Also, current flow is always from (+) to (−) according to the conventional theory, or from (−) to (+) according to the electron theory.

A wire cutting across a magnetic field also becomes a source of electricity, and therefore it must also have a (+) and (−) pole, just like a battery.

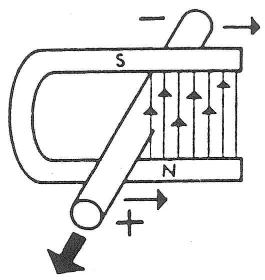


FIGURE 2-45
Reverse polarity of the same conductor as it passes back through the field. (Courtesy of Delco Remy)

However, unlike the battery, the wire's polarity can change at its end. The polarity depends on the relative direction of conductor movement through the magnetic field or the direction of the field travel itself.

Figures 2-44 and 2-45 illustrate this point. Figure 2-44 shows a straight conductor moving to the left across the magnetic field. With this direction of movement, the magnetic lines strike the wire on its left side, the leading edge. This induces voltage in the conductor and causes current to flow in it away from the reader.

When the direction of the motion of the wire reverses (Fig. 2-45) and moves toward the right, the right side of the conductor becomes the leading edge. Consequently, the induction of voltage reverses, and the resulting current flow is toward the reader. This means that the voltage polarity at the wire ends has reversed itself.

If instead of moving the wire to the left, as shown in Fig. 2-44, the magnetic field moves to the right across a stationary conductor, the same voltage induction and current flow occur. The same holds true for moving the field to the left across a wire. In each case, the leading side of the conductor and the magnetic-field direction are unchanged. In other words, voltage induction in a conductor can occur by moving it across a stationary magnetic field or moving the field across a stationary wire. It really does not matter which, *as long as there is relative movement between the two.*

Methods of Inducing Voltage

Basically, there are three ways to create voltage through the principle of electromagnetism: (1) by moving a wire through a magnetic field, (2) by self-induction, and (3) by mutual induction. A direct current (DC) generator produces voltage by moving a

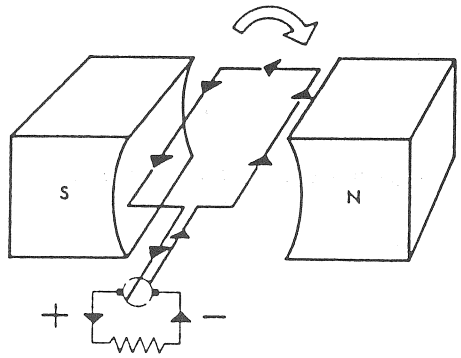


FIGURE 2-46
Basic DC generator. (Courtesy of Delco Remy)

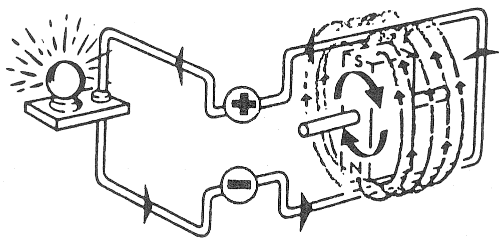


FIGURE 2-47
Basic alternator. (Courtesy of Delco Remy)

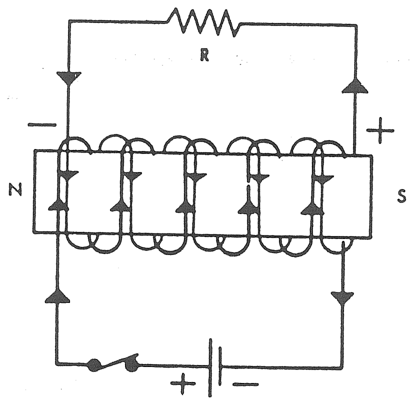


FIGURE 2-48
Mutual induction in the second coil when the circuit to the first coil is closed. (Courtesy of Delco Remy)

number of wires across a stationary magnetic field (Fig. 2-46). This illustration shows a basic type of DC generator, where a single turn of wire rotates between the N and S poles of a magnetic field.

In the position shown, current flows within the loop, as indicated. Due to the voltage induced into the turn of wire, there is polarity at the two commutator segements attached to the wire ends. The current can then flow through the brushes, riding on the commutator and out into the external circuit.

Note: The generator, due to its design, is able to produce voltage even if no current passes out of it and into an external circuit.

The alternator is another application of the principle of induced voltage (Fig. 2-47). But in this instance, the magnetic field cuts across a stationary wire in order to produce voltage and then current flow. The basic alternator has a rotating magnetic field that cuts across a stationary conductor mounted on a frame. As you can see with the rotating field position in Fig. 2-47, current flows through the conductor with the voltage polarity as shown.

Self-Induction

Self-induction, or *inductance*, is voltage generation in a conductor when current flow in the wire itself changes. In the two previous illustrations, an external magnetic field produced voltage in a wire as it moved through the conductor. In the self-induction process, no separate field is necessary. Instead, the magnetic field created by a changing current flow in the conductor induces voltage in the wire itself. Thus, the wire's own magnetic field causes this self-induction of voltage.

Since the current flow, to start with, creates a magnetic field in the form of concentric circles around the wire, which expand and contract as current flow increases or decreases, these magnetic lines cut across the conductor itself and thereby induce a voltage within it. The condition for inducing the voltage has been met because there is relative motion between the field and the conductor.

Mutual Induction

If a magnetic field produced by current flow in one electromagnetic coil cuts across the windings of a second coil, the field from the first coil induces a voltage in the second. This induction of voltage in one coil as a result of electromagnetism from another coil is known as *mutual induction*. Figure 2-48 shows this principle of mutual induction in a circuit where a second winding is wound around an iron core. The windings of the first coil are then wrapped around those of the second.

With this arrangement, when the switch closes, current begins to flow in the first coil, causing its magnetic field to expand and cut across the windings of the second coil. This action causes a voltage induction in the second coil and current flow

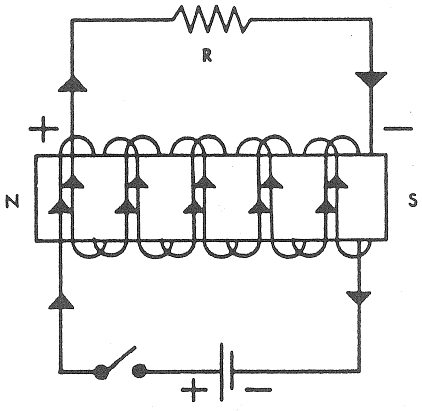


FIGURE 2-49
Mutual induction in the second coil when the circuit to the first coil is open. (Courtesy of Delco Remy)

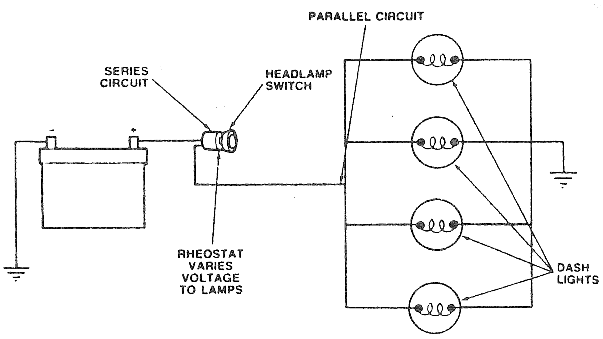


FIGURE 2-50
Manually operated headlamp switch. (Courtesy of Chrysler Corp.)

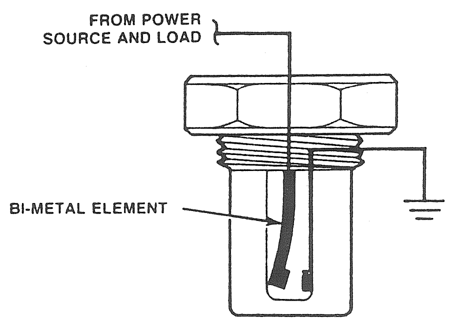


FIGURE 2-51
Typical coolant temperature switch. (Courtesy of Ford Motor Co.)

through the resistor in the direction shown.

Similarly, when the switch opens (Fig. 2-49), the sudden decrease in the current flow in the first coil causes its magnetic field to shrink and pass through the windings of the second coil once more. This also induces a voltage with an opposite polarity in the second coil, so the direction of current flow through the resistor reverses itself. In either case, the windings of the second coil become a source of voltage that can provide a source of current flow to an external circuit.

2-8 ELECTRICAL CONTROL DEVICES

All electrical systems contain a number of control devices. These regulate the flow of current from the battery to the various circuits of a vehicle. The most common types of control devices are the switch, relay, solenoid, and resistor.

Manual Switches

Electrical switches are used to open, close, or direct the flow of current in a circuit. A switch has contacts made of special metal alloys. These metals resist burning and corrosion by small electrical arcs that form as the switch opens and closes.

Many of the switches found on the automobile operate manually (Fig. 2-50). This means that the driver must manipulate a control knob on the switch to operate a given circuit. The control knob, through a rod or linkage, then closes or opens the contact points. When the points close, the positive side of the battery is connected into the circuit and current flows.

Manual switches are used to operate such circuits as the starter; ignition; headlights; radio or tape player; air conditioner and heater; windshield wiper and defogger; and power seats, windows, or door locks.

Automatic Switches

An *automatic switch* is also a device that opens or closes a circuit. However, in this case, the points within the switch are controlled by a material or mechanism activated by heat, pressure, or vacuum.

When the contacts are closed in this type of switch, they can also connect a circuit to the positive side of the battery. But in many cases, the closed points complete the ground (−) portion of the circuit back to the battery.

Typical examples of automatic switches are coolant temperature (Fig. 2-51), low oil pressure warning, vacuum, and brake warning lamp.

Relays

A *relay* is an electromagnetic type of switch that uses a small amount of current to trigger the flow of a large amount of current. The relay is usually used in circuits carrying high current flow, where long, large wires are expensive and awkward to use. Examples of relays found on automobiles are the horn, starter, radiator electric fan, air conditioner, power window, and fuel pump.

A typical relay consists of an electromagnetic coil and a pair of contact points (Fig. 2-52). The coil consists of many turns of fine wire wound around a laminated soft iron core. One end of the coil connects to the positive side of the battery. The other connects to one of the horn switch contacts. When closed, the horn button, or switch, will complete the ground portion of the relay coil circuit.

One of the relay points attaches to a movable armature arm that mounts above the electromagnetic coil. A spring hinge maintains the arm and the contact point in the open position when there is no current flowing in the coil. The stationary contact attaches to a wire that carries the heavy current flow from the battery to the horn itself.

When the driver depresses the horn button, it completes the ground circuit and a small amount of current flows through the coil. It, in turn, forms a strong electromagnet that attracts the armature arm down to close the two contact points. A heavy current can now flow to the horn.

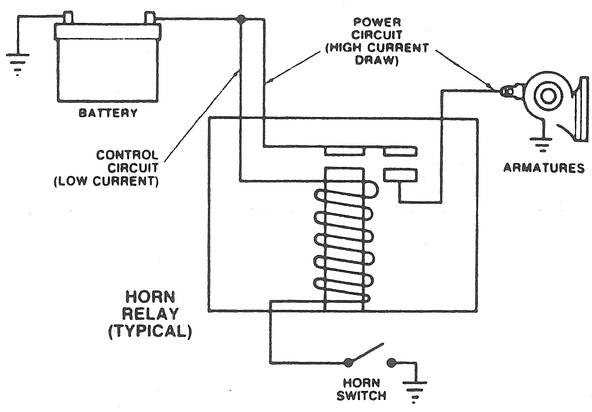


FIGURE 2-52
Schematic of relay construction. (Courtesy of Chrysler Motors Corp.)

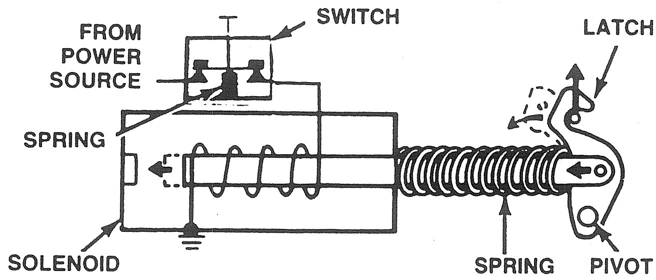


FIGURE 2-53
Luggage compartment solenoid schematic. (Courtesy of Ford Motor Co.)

Solenoids

A *solenoid* is an electromagnet with a movable instead of a fixed iron core. The solenoid can have two basic functions. First, it can be used to convert electrical current flow into mechanical movement to do some type of work. Second, the solenoid can act as a relay to close a second set of contact points to control a heavy current flow.

Figure 2-53 illustrates a typical solenoid that is used to operate a luggage compartment latch. Solenoids of a similar design are also used as actuators for a number of applications in electronic control systems. The solenoid shown consists of a set of windings and a core. One end of windings connects to ground and the other to the battery positive terminal via the manual switch contacts.

The core is a piece of iron that slides into the air gap inside the windings. Over one end of the core fits a return spring that keeps it extended when the coil is de-energized. This end of the core also attaches to the latch, which can pivot back and forth.

When the manual switch is pressed in, current flows through the windings of the solenoid, energizing the coil. The coil now becomes an electromagnet that pulls the core inward. This action pulls on the latch, releasing the luggage compartment lid.

When the switch is released, current ceases to flow in the solenoid circuit. As a result, the coil loses its electromagnetism, and the spring moves the core outward, resetting the latch in the closed position.

Solenoids that operate under a heavier load usually have two windings (Fig. 2-54). The heavy set (known as the primary or pull-in) is necessary to help pull the core into the coil. The lighter windings, called the hold-in or secondary windings, can maintain the core in place once it is drawn in.

In operation, current flow from the battery passes through both sets of windings and to ground. This produces a large enough magnetic field to pull the core into the air gap.

As the core bottoms in the solenoid, it contacts

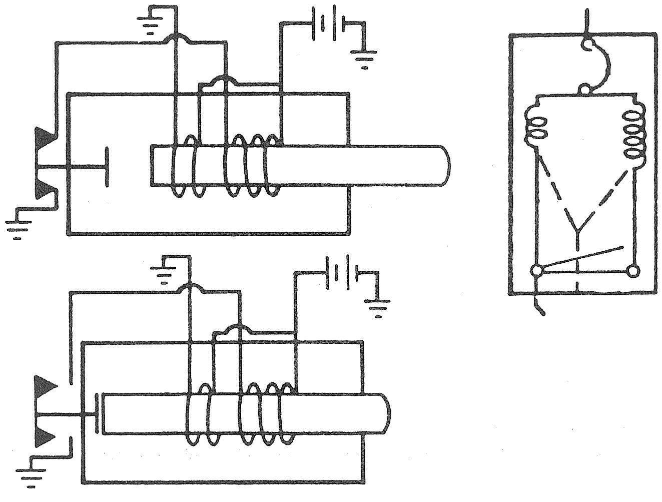


FIGURE 2-54
Diagram of a compound-wound solenoid. (Courtesy of Ford Motor Co.)

a switch that opens. This action breaks the ground circuit for the pull-in windings. As a result, there is a reduction in current flow through the solenoid. However, the reduced flow through the hold-in windings is enough to produce sufficient magnetism to hold the core in position.

Resistors

A *resistor* is an electrical component used to limit current flow and thereby voltage in a circuit as needed. Resistors (Fig. 2-55) are conductors specially constructed to introduce a measured amount of electrical resistance into a given circuit. However, some other circuit components use built-in resistance to produce heat, light, or both, such as cigarette lighters and light bulbs.

Resistors in common use in automotive circuits are of three types: (1) fixed value, (2) stepped or tapped, and (3) variable. A *fixed value resistor* is one designed to have only one rating that should not change. Resistors of this design are used for controlling circuit voltage and thus current flow. Common applications for this type are the ignition resistor and the carbon units used in ignition modules, radios, or computers.

A *tapped* or *stepped resistor* is designed to have two or more fixed values, attached by connecting wires to several taps on the resistor block. A typical example of this type of device is the blower motor resistor.

The *variable resistor* is designed to have a range of resistances available through two or more taps and a control. The headlight switch rheostat is an example of this type of resistor. This unit has two tap connections, one on the fixed end of a resistor and one attached to a sliding contact that rides on it. Turning the switch control moves the sliding contact away from or toward the fixed end of the resistor. This has the effect of increasing or decreasing the resistance in the dash light circuit that the rheostat controls.

There are two other types of variable resistors, the potentiometer and the thermistor. These devices are covered in Chapter 4.

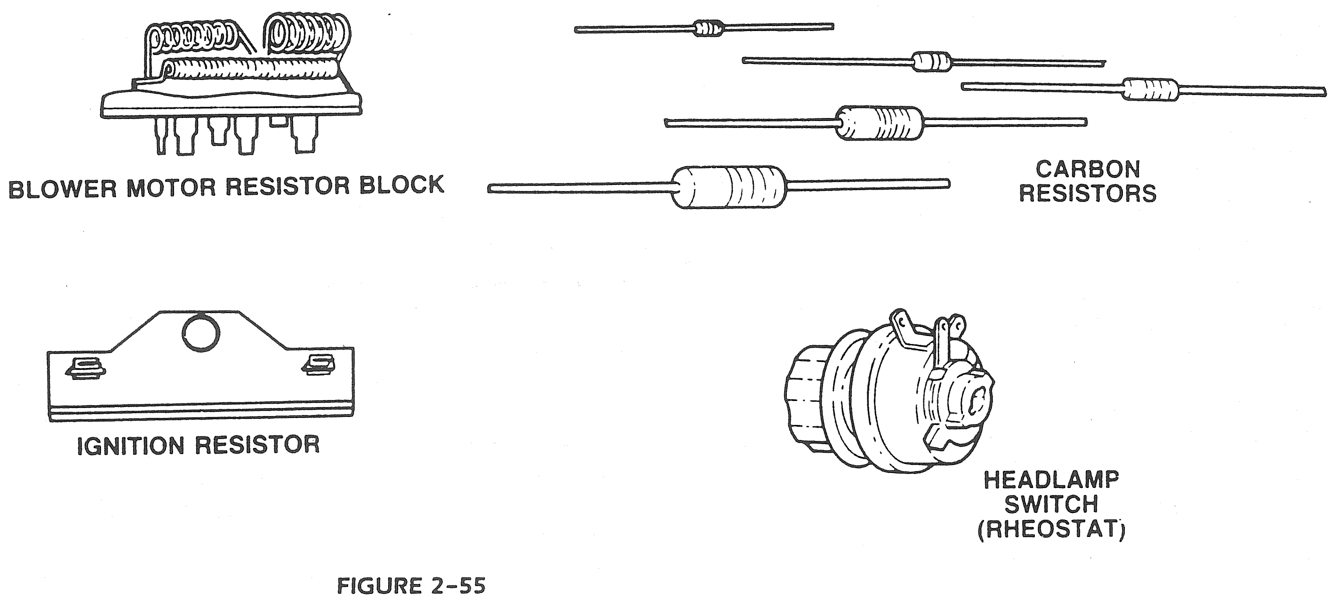


FIGURE 2-55
Automotive type resistors. (Courtesy of Chrysler Motors Corp.)

Circuit Protection Devices

Automotive electrical circuits have some kind of protective device. This device safeguards the circuit from damage when an overload causes too much current to flow. The excessive current would otherwise cause the wiring to heat up, possibly melting the insulation and maybe causing a fire. The common types of protection devices are the fuse, fuse link, and circuit breaker (Fig. 2-56).

The fuse is the most common form of circuit protection used in automobiles. Several types of fuses are used by manufacturers; they include the glass tube style and the plastic blade design. The glass tube style contains an element strip of metal with a low melting point. If an excessive current flows through the circuit with either style of fuse, the fuse element melts at the narrow portion, opening the circuit and preventing damage to the electrical component.

A fuse is designed to carry a specified maximum current flow and to blow when this value is exceeded. The maximum fuse current flow is marked on the fuse in amperes (A). *A blown fuse must always be replaced with one that has the same design and current-carrying capacity. Do not, for example, replace a 15A fuse with a 20A fuse.*

A fuse block or panel serves as the common connection point for a number of wires or wiring harnesses. Fuses are inserted between the connecting points of the wires. This design protects each circuit against electrical overloads and also groups the fuses in a convenient location.

Some wiring harnesses are equipped with a *fusible link* to protect them against damage in the event of a short in a main feed circuit. The link itself (see Fig. 2-56) is a short length of wire smaller in gauge than the conductor in the circuit it protects. The link is installed in the conductor, usually close to the power source. In addition, the fusible link wire is covered with thick, nonflammable insulation.

If a circuit overload occurs, the link will melt, causing the circuit to open. Moreover, the heat from the overload usually causes the link's insulation to smoke or blister.

Fusible links are replaced by cutting them out of the conductor and installing a replacement of the same rating. *Do not replace a blown link with standard gauge wire. Only fusible-link-type wire with hypalon insulation must be used or damage to the electrical system will occur.*

Some special electrical components and wiring harnesses are protected by *circuit breakers.* These circuits (such as the headlights or wipers) may sometimes undergo a temporary overload, yet they must have power restored rapidly. A fuse and fuse link are no good in these cases because they may not be readily available for replacement. A circuit breaker can be mounted in a fuse block or in-line with a particular circuit. Also, like fuses, circuit breakers are rated by their ampere-carrying capacity.

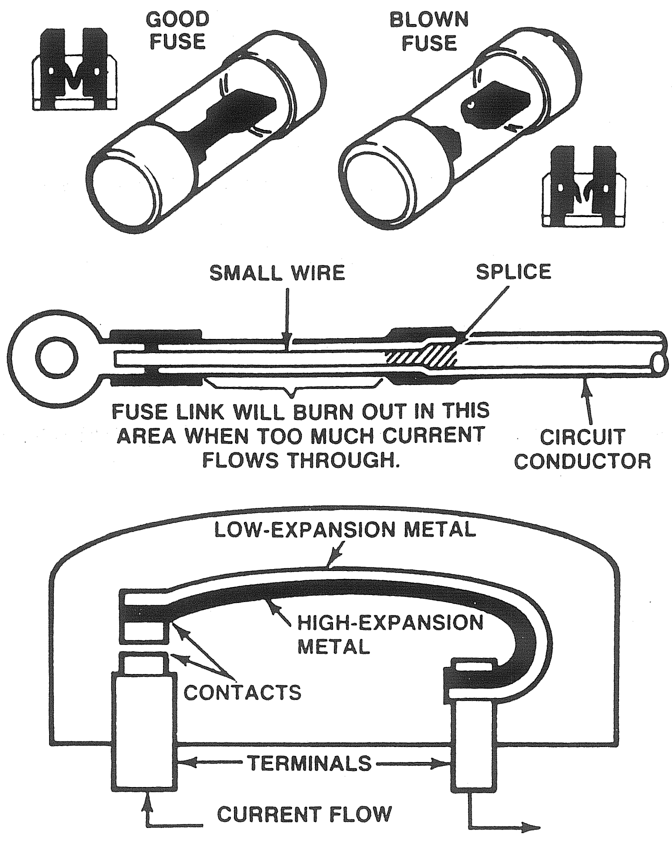


FIGURE 2-56
Circuit protection devices. (Courtesy of Ford Motor Co.)

A circuit breaker consists of a set of contacts controlled by a strip made of two kinds of metal bonded together. Each strip of metal has a different coefficient of expansion.

When an overload occurs and excessive current flows through the bimetallic strip, it heats up and bends due to the uneven expansion of the two metals. This action very quickly opens the contact points and the circuit.

With no current flowing, the bimetallic strip cools and straightens out, closing the contact points. This once again closes the circuit. If the overload is continuous, the circuit breaker will cycle open and closed until the source of the problem is corrected. If the overload is removed, the breaker will remain closed, and the circuit will continue to function in a normal manner.

This type of breaker is called *self-resetting* because it automatically reconnects the power to the circuit after protecting it against an overload. *Manually resettable circuit breakers* are also sometimes used. On this type, a button will pop out of the circuit breaker case, indicating the points have opened. To reset this breaker design, it is simply a matter of pushing in the button.

Keep in mind that just replacing a fuse, fusible link, or resetting a circuit breaker does nothing toward remedying the problem that caused the overload. Indeed, the action may be fruitless because the fuse or breaker will again blow as soon as the circuit is switched on. *Always repair the source of the overload before restoring the circuit protection device.*

2-9 WIRING DIAGRAMS AND SYMBOLS

Each year, all vehicle manufacturers issue wiring diagrams for the electrical system found on each of their production vehicles (Fig. 2-57). A *wiring diagram* is a graphic representation of the components and conductors within the electrical system. These diagrams are incorporated into the service manual for the particular vehicle. In addition, publishers such as Chilton, Motors, and Mitchell Manuals provide wiring diagrams for domestic and imported vehicles.

In either case, a diagram is as informative as a road map once you understand the numbers and symbols shown on it. Without a diagram, diagnosis and repair of electrical circuits would be almost impossible; with one, you can make your way quickly to where you need to go to locate the source of a problem.

In this chapter and others, you will see a type of diagram that shows actual components connected by conductors. This is known as a *pictorial diagram*, and is a crossbreed between the actual likeness of a component and what is shown on a true *schematic diagram*. Pictorial diagrams are useful in training because they relate the familiar to the unfamiliar. Schematic diagrams, on the other hand, are more informative. They usually show component internal electrical paths and squeeze more information into a smaller space.

Diagram Symbols

All parts of wiring diagrams have symbols that represent the actual physical parts used in the system.

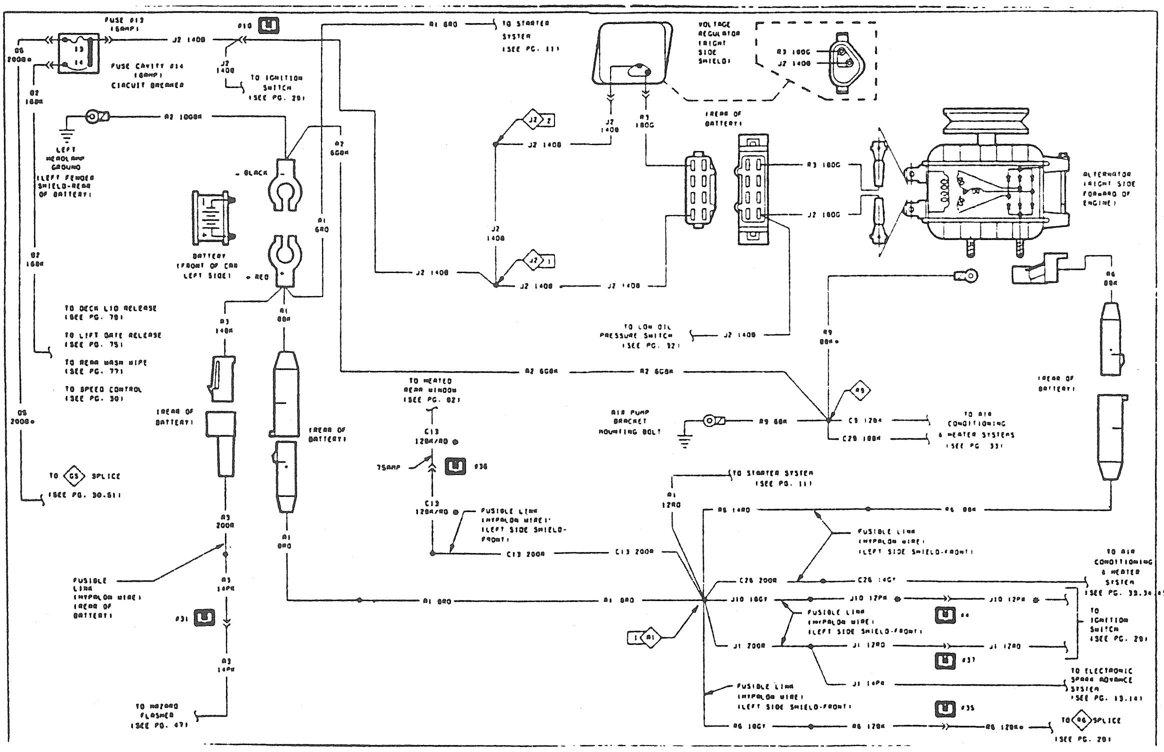


FIGURE 2-57
Typical wiring diagram. (Courtesy of Chrysler Motors Corp.)

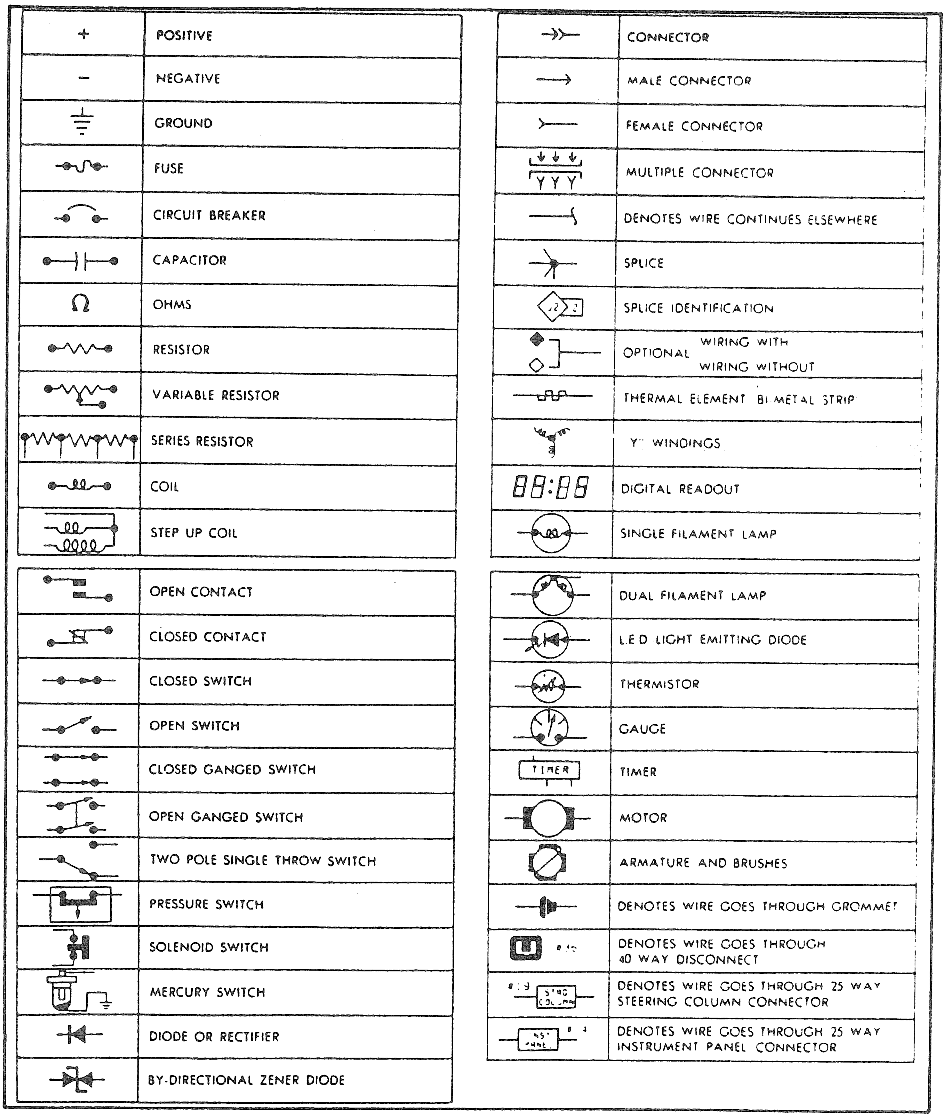


FIGURE 2–58
Common wiring diagram symbols. (Courtesy of Chrysler Motors Corp.)

In some cases, the symbol looks just like the part, and other times, it's rearranged to fit more easily into the diagram and keep it simple.

There are wide variations in the use of automotive electrical symbols. Some companies use their component drawings for some units and standard symbols for others (Fig. 2–58). Moreover, the component's basic internal circuit is sometimes shown, while in other cases, symbols are used all of the time.

Figure 2–58 is a legend of the various symbols and their descriptions provided by Chrysler Corporation as an aid in following its diagrams. Other manufacturers provide the same type of information in their service manuals.

Become very familiar with the symbols used on the diagram with which you are going to work. These symbols represent the components, wires, and connectors exactly the way you will find them in the circuitry of that particular vehicle. You will find more information on reading diagrams in Chapter 5.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. Explain the purpose of a relay [2-8].
2. What determines the classification of matter [2-1]?
3. What factors determine the strength of an electromagnet [2-7]?
4. According to the electron theory, what is current flow [2-2]?
5. What is the basic law of magnetism [2-6]?
6. Current flow can be compared to what [2-3]?
7. What are the three forms of the equation for Ohm's law [2-4]?
8. Describe the basic difference between a series and a parallel circuit [2-5].
9. What is the difference between a fixed and tapped resistor [2-8]?
10. Explain the purposes of pictorial and schematic diagrams [2-9].

REVIEW

1. The electromagnet with a movable core is called [2-8]
   a. a relay.
   b. a solenoid.
   c. an ignition coil.
   d. a tapped resistor.
2. The nucleus of an atom is formed of [2-1]
   a. protons and neutrons.
   b. electrons and protons.
   c. neutrons and electrons.
   d. none of these.
3. The use of an iron core increases the strength of an electromagnet about how much [2-7]?
   a. 1,000 times
   b. 1,500 times
   c. 2,000 times
   d. 2,500 times
4. Electrons that are easily lost from their orbits are known as [2-2]
   a. drift electrons.
   b. bound electrons.
   c. balance electrons.
   d. free electrons.
5. What is a natural magnetic material [2-6]?
   a. lodestone
   b. steel
   c. iron
   d. aluminum
6. Electrical pressure can also be called [2-3]
   a. voltage.
   b. EMF.
   c. both a and b.
   d. neither a nor b.
7. To find the amount of amperes in a circuit, which form of Ohm's law should you use [2-4]?
   a. $I = E \times R$
   b. $I = E \div R$
   c. $E = I \times R$
   d. $R + E \div R$
8. Which type of circuit has the same current flow through all the resistance units [2-5]?
   a. parallel
   b. series
   c. series-parallel
   d. both b and c
9. A headlight circuit usually has what type of protection device [2-8]?
   a. fuse
   b. fusible link
   c. fuse and link
   d. circuit breaker
10. How many electrons does a copper atom have in its outer orbit [2-1]?
    a. 1
    b. 7
    c. 9
    d. 13

11. What factor changes the direction of the lines of force around a conductor [2-7]?
    a. increasing its resistance
    b. reversing the current flow through it
    c. decreasing its resistance
    d. increasing the applied voltage

12. Bakelite is what type of material [2-2]?
    a. semiconductor
    b. conductor
    c. resistor
    d. insulator

13. Like magnetic poles [2-6]
    a. attract each other.
    b. are neutral toward each other.
    c. repel one another.
    d. do none of the above.

14. Which type of circuit has a voltage drop equal to the battery across each resistance unit [2-5]?
    a. parallel
    b. series
    c. series-parallel
    d. none of the above

15. According to Ohm's law, if voltage remains the same and resistance is increased current will [2-4]
    a. increase.
    b. decrease.
    c. remain the same.
    d. do none of the above.

16. The measurement for current flow is the [2-3]
    a. volt.
    b. ohm.
    c. volt-ohm.
    d. ampere.

17. An electrical control that performs mechanical work is the [2-8]
    a. switch.
    b. solenoid.
    c. coil.
    d. fusible link.

18. A lack of electrons exists at which battery terminal [2-2]?
    a. positive
    b. negative
    c. neither terminal
    d. both terminals

19. If a battery connected into a circuit has a difference in electrical charges at its terminals, what will occur [2-3]?
    a. voltage
    b. current flow
    c. both a and b
    d. neither a nor b

20. A shorted circuit can cause what condition [2-5]?
    a. decrease in current flow
    b. increase in current flow
    c. no change in current flow
    d. increase in system voltage

Chapter 3

ELECTRONIC FUNDAMENTALS

OBJECTIVES

After reading and studying this chapter, you will be able to:

- explain the structure and operation of a semiconductor.
- describe the function, design, and operation of a standard, zener, and light-emitting diode.
- explain the purpose, structure, and operation of a transistor.
- describe the function, design, and operation of a capacitor.
- identify and know the purpose of an integrated circuit.
- describe a microelectronic chip and know its purpose.
- explain basically how a memory cell can store information.

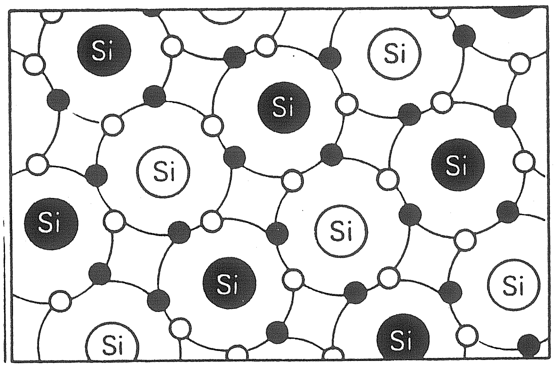


FIGURE 3-1
Crystalline silicon is an excellent insulator. (Courtesy of Delco Remy)

Years ago, the term *electronics* meant a study of the behavior of electrons in vacuum tubes and the devices (radios and televisions) that used them. Now the word has come to mean the flow of electrons through a radio tube or its equivalent. The equivalent in this instance means electron flow through semiconductors such as diodes and transistors.

Semiconductors have been especially important to the development of alternators, ignition systems, computerized engine controls, and other solid state equipment. *Solid state* refers to any device that uses transistors, diodes, and other components made from semiconductors. To understand the electronic equipment presented in later chapters in this text, it is necessary for the reader to have a basic understanding of the structure of semiconductors and how they are formed into diodes, transistors, and integrated circuits.

3-1 SEMICONDUCTORS

A semiconductor, as a form of matter, falls somewhere between a conductor and a nonconductor. In other words, it is a material that is neither a good conductor nor a good insulator. The difference is due primarily to the number and arrangement of electrons and the way in which atoms are joined.

Structure of a Semiconductor

As mentioned, materials that have atoms with less than four electrons in the outer orbit are good conductors and those having five or more are good insulators. Atoms with exactly four electrons in the outer orbit are neither good conductors nor good insulators; however, they do form good semiconductors. *Silicon* and *germanium* represent materials of this type, with silicon the most predominantly used material for semiconductors in automotive circuits. For this reason, the following discussion will concentrate on silicon-based semiconductors.

When a number of these silicon atoms are combined chemically in crystalline form, the result is called *covalent bonding*. This means that the electrons in the outer orbit of one atom join with those in the outer orbit or another atom (Fig. 3-1). In effect, each atom has eight electrons in its outer orbit, four of its own and four shared with another silicon atom. This makes the material a good insulator because there are no free electrons.

But when certain other materials are added to the highly refined silicon crystal in very controlled amounts, the resultant mixture is said to be *doped*. The doping elements are often called *impurities* because their addition to the semiconductor makes its original base material impure. As a result of the doping, the silicon material is no longer a very good insulator, and it possesses some unusual electrical properties.

N Material. If silicon, for example, is slightly doped with an element such as phosphorus, arsenic, or antimony (also in crystalline form) at a ratio of 1 part to 10,000,000 parts of silicon, the result then becomes an *N material* (Fig. 3-2). Each of these doping materials has five electrons in its outer orbit. When phosphorus is combined with the silicon, covalent bonding does occur. However, in this case, there is one electron left over. In other words, there will not be enough space for the ninth electron in the shared outer orbits of the phosphorus and silicon atoms.

This electron is free and can be made to move through the entire material very easily. Any material having extra electrons is called negative or N

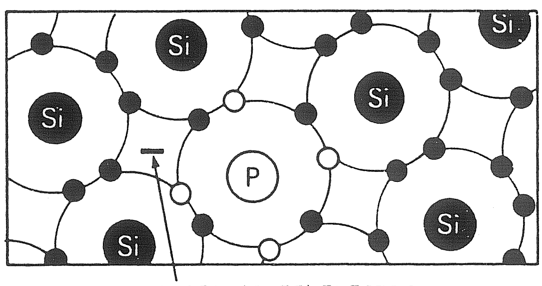


FIGURE 3-2
Using phosphorus to dope silicon leaves a free electron in silicon's outer orbit. (Courtesy of Delco Remy)

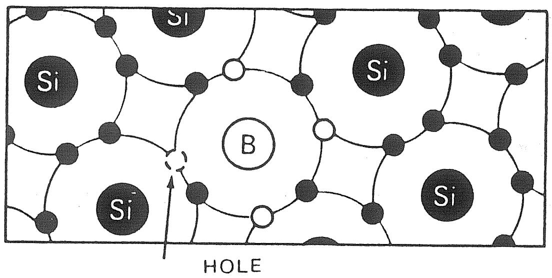


FIGURE 3-3
Using boron to dope silicon creates a hole in silicon's outer orbit. (Courtesy of Delco Remy)

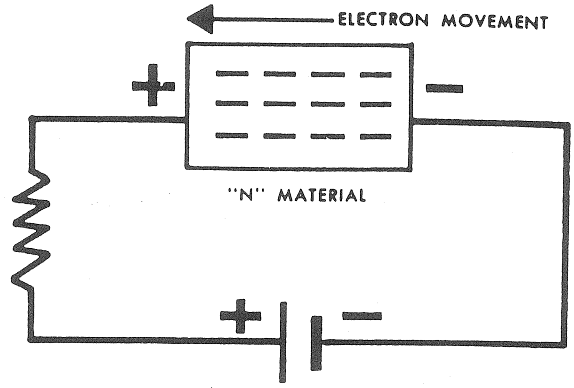


FIGURE 3-4
Electron flow in a circuit with N-type material. (Courtesy of Delco Remy)

material. That is, the material already has excess electrons that will repel additional negative or attract more positive charges.

P Material. On the other hand, when silicon is doped with impurities such as small particles of boron or indium crystals, it then becomes a *P material* (Fig. 3-3). Both of these doping materials have three electrons in their outer orbits. So when convalent bonding occurs between the silicon and atoms of the doping material, there is a deficiency of one electron needed to fill the shared outer orbit.

The resultant void is called a *hole.* A hole is the absence of an electron required to fill an atom's outer orbit. While the electron has a negative charge of electricity, the hole can be considered a positive charge of electricity. Materials of this type are known as positive or P materials because they will attract a negative or repel an additional positive charge.

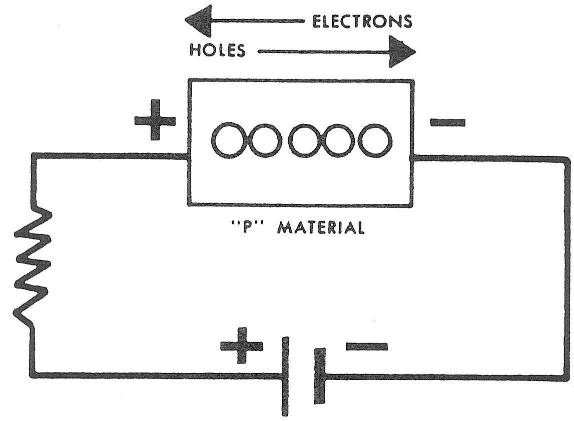


FIGURE 3-5
Movement of electrons and holes within the circuit with P-type material. (Courtesy of Delco Remy)

Semiconductor Operation

To better understand the operation of a semiconductor, consider the extra electron in the N material as a negative (−) charge, and the hole in the P material as a positive (+) charge. The hole can move from atom to atom in the same way an electron can due to the influence of electromotive force (EMF).

Figure 3-4 illustrates current flow in an N-type material. By connecting a battery and a resistor into a circuit with the material, current flows. This flow is the movement of the excess or free electrons through the material and is very similar to what occurs in a good conductor, a copper wire. The negative side of the circuit pushes electrons through the semiconductor, and the positive side attracts the free electrons.

The movement of holes and electrons in a P-type material is shown in Fig. 3-5. When voltage is applied to the material, it produces a directed pattern of holes and moving electrons. As mentioned, current (according to the electron theory) is the movement of electrons from negative to positive. But current in the P-type semiconductor is looked on as movement of the positively charged holes from positive to negative just like current flow is described in a good conductor using the conventional theory. In other words, the hole effectively moves from atom to atom in one direction, just like an electron travels from atom to atom in the opposite direction.

Figure 3-6 further illustrates this hole movement. Notice how the positive battery terminal in diagram 1 attracts a negative electron from one of the covalent bonds within the P material into the hole next to the terminal (i.e., unlike charges attract

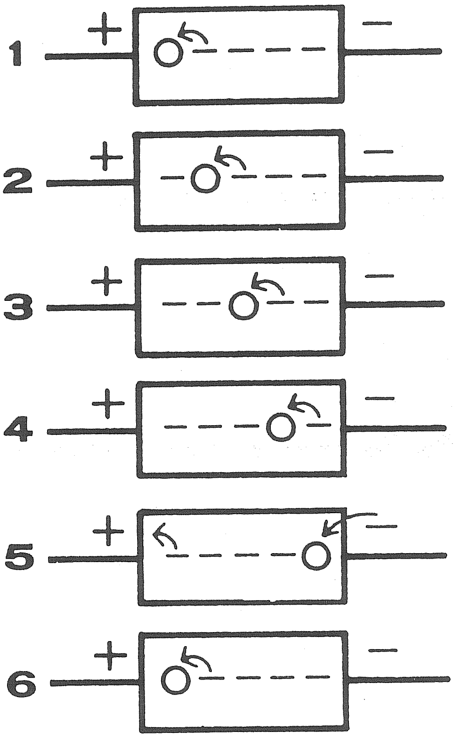


FIGURE 3-6
Movement of holes within a P-type material. (Courtesy of Delco Remy)

one another). Similarly, the negative battery terminal repels an electron through its connection.

This movement of an electron leaves behind a hole (diagram 2). The positively charged hole has, in effect, moved to the right or toward the negative terminal of the battery. Another electron will then move in to fill this hole, creating yet another hole nearer the negative terminal.

This process continues in this manner as the hole moves to the right. Finally, the hole arrives in the vicinity of the negative terminal of the semiconductor (diagram 5). At this time, the hole again is filled by an electron that leaves the negative terminal, while the positive terminal removes an electron from the semiconductor. In diagram 6, the positive terminal repels a hole into the semiconductor, and the process is then ready to repeat itself all over again as described above.

As mentioned, this continuous movement of the holes from the positive to the negative terminal can be considerd as current flow in a P-type material. And this action can only occur when voltage causes the electrons to shift around in the covalent bonds.

However, it is important to note that the hole movement only occurs within the semiconductor, while electrons flow through the entire circuit. Finally, the theory of hole movement affords an easier way to understand how diodes and transistors operate.

3-2 DIODES

As stated, the N- and P-type materials are both semiconductors. As such, they can conduct current flow in some applications, while in others they act as insulators. The first practical, production-line use of N- and P-type semiconductor materials in the automotive industry was in the construction of diodes for use in the alternator. In the alternator, diodes are used to rectify current from AC to DC for use in the charging system. Later, of course, the diode was extensively used in ignition modules and computerized engine control systems.

Diode Function

A *diode* is an electronic component that allows current to pass through itself in one direction only, like a one-way valve, because the unit offers low resistance in one direction only. A diagram and symbol for the diode are shown in Fig. 3-7. Notice that the arrow in the symbol points in the direction of hole movement, or current flow using the conventional theory.

Typical Diode Construction

Manufacturers construct a diode by changing silicon crystal into N-type and P-type materials and forming the two together. The process of forming the two types of material involves not just a mechanical union, but a carefully controlled manufacturing technique that creates and joins the two parts in a diffusion process. *Diffusion* is a process by which particles of the impurities and the silicon intermingle as a result of thermoagitation.

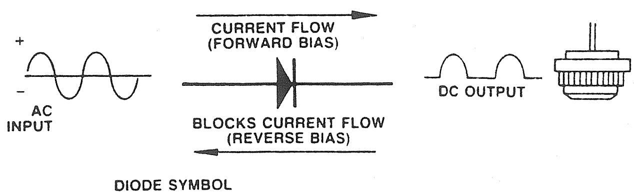


FIGURE 3-7
Typical automotive diode. (Courtesy of Chrysler Motors Corp.)

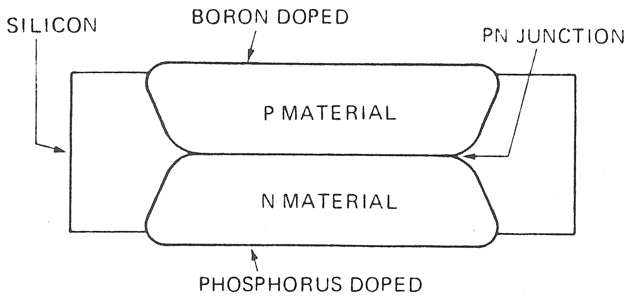


FIGURE 3–8
Diode wafer design.

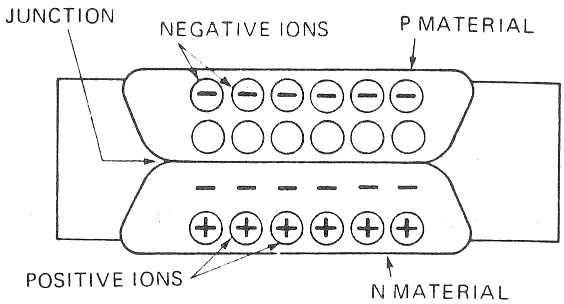


FIGURE 3–9
Static diode operation.

The process itself involves a wafer of silicon about 0.007 inch thick and 1-½ inches in diameter. The wafer is first painted on one side with a solution containing phosphorus pentoxide and on the other side with one containing boric oxide. Next, the painted, or doped, wafer is positioned into a furnace containing a hydrogen atmosphere at 1,200°C. Under these conditions, the compounds phosphorus pentoxide and boric oxide are chemically drawn together. This produces boron and phosphorus, which diffuse into the silicon to form P-type and N-type materials respectively (Fig. 3-8). The internal area of the diode where the P-type and N-type materials meet is known as the *junction.*

The manufacturer then plates the wafer to facilitate the soldering of electrical connectors before breaking it up into smaller pieces. This sizing operation is necessary to incorporate the diode into a given electrical circuit.

Diode Operation

There are three phases of diode operation: static, forward bias, and reverse bias. During the *static phase,* the diode is not connected into an electrical circuit (Fig. 3-9). When P-type and N-type materials are formed into a diode, an attraction exists between the free electrons and holes. It would seem then that the N material's free electrons would drift across the junction area and fill the holes within the P material.

This action does occur, but only to a very limited extent. As a few electrons from the N material do drift toward the junction, they leave behind charged particles called positive ions. An *ion* is an atom having a deficiency or excess of electrons. These positive ions exert an attractive force on the remaining free electrons to prevent them from crossing the junction.

In a similar manner, a few holes from the P material cross the junction. When they do, the holes leave behind negative ions, which exert an attractive force on the remaining holes to prevent them from crossing the junction. The net result is a balanced condition with a deficiency of electrons and holes at the junction area. The electron and hole drift, in effect, is an insignificant amount and does not measurably affect diode operation.

When a diode is connected into a circuit with a battery and a resistor, as shown in Fig. 3-10, the situation changes. As indicated, the diode is connected into the circuit with the negative side of the battery connected to the N-type material and the positive terminal attached to the P-type material. This is known as a *forward-bias connection. Biasing* is the application of voltage to the two doped semiconductor materials.

With this type of connection, the negative terminal of the battery will repel electrons into the N-type material, and the positive terminal will repel the holes into the P-type material. The electrons moving into the N-type material satisfy the positive ions that had been holding other electrons away from the junction. With this restraining force satisfied, electrons at the junction move across and on through the circuit.

As electrons move across, they leave behind positively charged holes in the N material, which at-

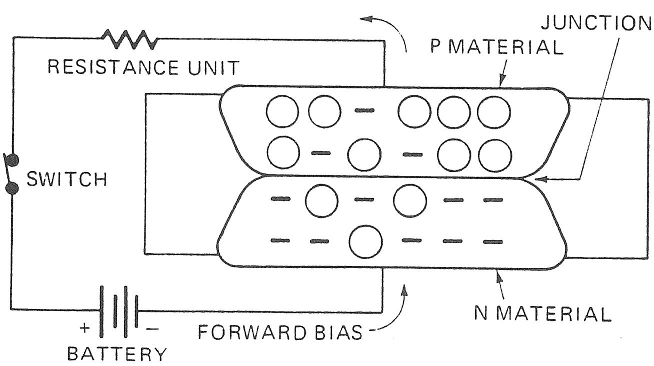


FIGURE 3–10
Diode operation in a forward-bias connected circuit.

tract more electrons from the negative battery terminal. At the same time, the free electrons that moved into the P material continue to be attracted toward the positive battery terminal, leaving behind holes in the P-type semiconductor at the junction.

In a similar manner, the additional holes entering the P material from the positive terminal satisfy the negative ions that had been holding the holes away from crossing the junction. With this restraining force also satisfied, holes at the junction move across and through the N material.

As the electrons move from the N to the P material, the battery continues to inject electrons into the N-type and attract electrons from the P-type material to maintain a given rate of electron movement. Thus, there is current flow: holes in one direction and electrons in the other.

An important factor to note, however, is that in order for an appreciable amount of current to flow through the diode, there must be *a concentration of holes in the P material near the junction,* and *a concentration of electrons in the N material near the junction.* This is necessary because in order for electrons to move into the P material, there must be holes present at the junction *into which the electrons can move.* In other words, if there are no holes present, the electrons have no place to go in the material. Consequently, there can be no flow.

Depending on its design, a diode can only withstand a given amount of forward-bias voltage and current flow. If the forward current flow is too strong or flows for too long a period, the doped materials can be damaged or destroyed.

Figure 3-11 illustrates a diode installed into a circuit using *reverse-bias connection.* In this case, the positive terminal of the battery attaches to the N-type material, while the negative connects to the P-type semiconductor.

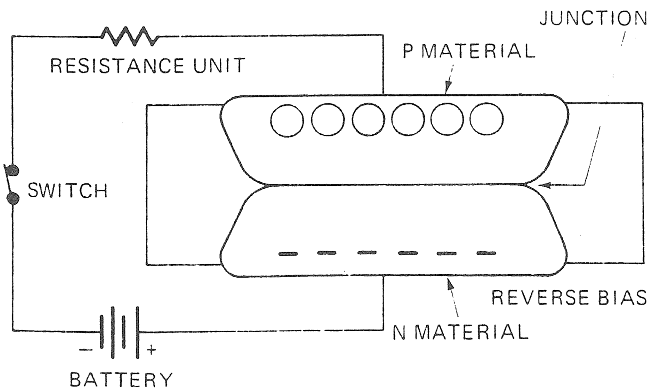


FIGURE 3-11
Diode operation in a reverse-bias connected circuit.

As shown, the positive battery terminal attracts the electrons away from the junction area in the N-type semiconductor. The negative terminal attracts the holes away from the junction area of the P-type material. As a result, the electrons and holes merely drift away from the junction area. Therefore, the electrons do not enter the circuit to create current flow.

With the junction area void of holes and electrons, there can be no appreciable current flow. In effect, the diode has a very high electrical resistance created at the junction area. Consequently, when the diode has a reverse-bias connection into a circuit, it blocks current flow. In other words, the diode permits current flow in one direction by acting as a conductor, but it stops current flow in the opposite direction by operating as an insulator.

However, because the diode is not a perfect insulator, a small amount of reverse current leakage does occur. But this amount is usually too small to consider.

Diode Performance Curve

Figure 3-12 shows a typical diode performance curve that illustrates the current flow for both forward- and reverse-bias voltages. Note how as the forward-bias voltage goes up, the forward current flow tends to increase very rapidly.

The curve in the lower left portion of Fig. 3-12 shows that a current does flow when a reverse voltage is applied to the diode. The magnitude of the reverse current is very small, and it increases very little until the breakdown or maximum reverse voltage is reached.

One of the most common ways to rate a diode is in terms of its *peak inverse voltage (PIV).* This

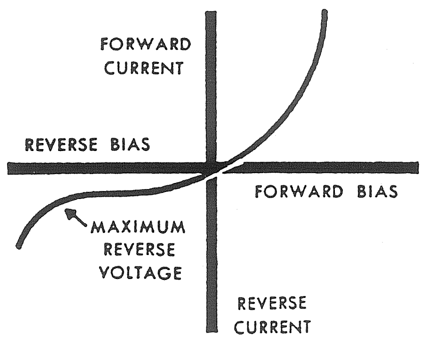


FIGURE 3-12
Diode performance curve. (Courtesy of Delco Remy)

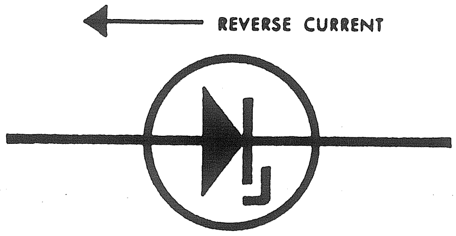


FIGURE 3-13
Symbol for a zener diode. (Courtesy of Delco Remy)

refers to the amount of reverse-bias voltage the diode can withstand before breaking down and permitting excessive reverse current flow. A diode can withstand a reverse-bias voltage below its PIV rating indefinitely.

However, higher reverse current caused by increased reverse voltage above the PIV rating can quickly damage the diode. At a voltage above the PIV rating, the convalent bond structure of the semiconductor breaks down. This is followed by a rapid increase in current flow, which overheats and ruins the diode. Typical safe values for a given diode may be 2 or 3 amperes of forward current flow and less than 0.001 ampere of reverse current.

Zener Diode

A *zener diode* is a specially designed unit that will satisfactorily conduct current flow in the reverse direction. A symbol for this diode is shown in Fig. 3-13. The primary feature of this kind of diode is that it is very heavily doped during its manufacture. The process provides a large number of extra current carriers (electrons and holes). This allows the zener diode to conduct current in the reverse direction without damage; that is, as long as the zener is used in a properly designed circuit. Zener diodes are usually found in some form of voltage control circuitry.

The doping process is carefully controlled so that this diode type will only conduct reverse current if the voltage is higher than a specific level. For instance, a given zener diode may have a design to only conduct current if the reverse voltage is more than six volts. At any reverse voltage below six volts, the zener acts as a normal diode and does not conduct reverse current flow.

At six volts and above, the zener diode conducts reverse current flow with no damage to the doping materials within the semiconductors; that is, if the current flow is kept within specified limits. In the example given, the diode's *breakdown* or *zener voltage* is six volts.

Light-Emitting Diodes

A *light-emitting diode (LED)* is one made of a specially doped crystal that glows when current passes through it. When the two doping materials gallium and arsenic are formed with the silicon crystal, an interesting thing occurs within the semiconductor under forward-bias voltage. When a hole and an electron meet, they are neutralized as electrical charge carriers. As this occurs, electrical energy is released as light. If these diodes are arranged in geometrical shapes and then the current flow is turned on and off through selected units in a pattern, the result is a lighted LED display, as used in some automotive instruments.

3-3 TRANSISTOR

As mentioned in the last section, diodes can control the direction of current flow as well as the amount and polarity of voltage applied across all or a portion of a circuit. However, diodes cannot increase, or amplify, current or circuit voltage.

Electronic systems for such applications as voltage regulators, ignition modules, radios, and microcomputers usually require current or voltage amplification in order to develop sufficient power to perform given functions. The *transistor* (Fig. 3-14) is a semiconductor device that can perform this amplification. In addition, the transistor can work like a relay in electronic systems to switch a high-current circuit on and off using a voltage signal across a low-current circuit.

Transistor Design

Manufacturers usually form an individual transistor by adding a section of N- or P-type material to the PN junction used for diodes. This design results in either the PNP or the NPN transistor (Fig. 3-15). Notice that in each transistor the outer layers are the same kind of material (either P or N), and the

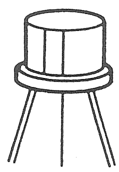


FIGURE 3-14
Typical transistor. (Courtesy of Chrysler Motors Corp.)

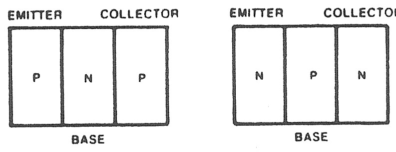


FIGURE 3-15
PNP and NPN transistors. (Courtesy of Chrysler Motors Corp.)

center layer is opposite. The name *transistor* comes from the words *transfer* plus *resistor* because this device transfers signals across the resistance of either two P or two N materials.

The three components of the transistor are the *base*, *emitter*, and the *collector* (see Figs. 3-15 and 3-16). When the transistor is part of an integrated circuit, the base is known as the *gate*, the emitter as the *source*, and the collector as the *drain*. In any case, the emitter and the collector are the outer layers and the base is the inner layer.

Notice also in Fig. 3-16 the arrowhead on each of the transistor symbols. The arrow is always on the emitter side and points in the direction of the hole or conventional current flow.

Figure 3-17 illustrates the design of a conventional, nonintegrated transistor. The three parts of the transistor are doped and constructed differently to affect the amount of current through the different areas. The base is thin and doped with a minimum number of carriers (holes or electrons), depending on transistor design. Moreover, attached around the base is a metallic ring, which will connect into an external electrical signal circuit. The signal applied to the base circuit controls the operation of the transistor.

The emitter is the thickest section of the transistor. The emitter is doped more than any other part in order to provide the maximum number of carriers.

The collector is not as thick as the emitter. In addition, this area is doped less. Therefore, it has fewer majority carriers (electrons in the NPN or holes in the PNP transistor). This design allows a reverse current flow when bias voltage is applied.

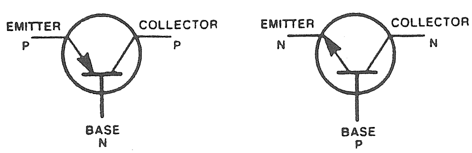


FIGURE 3-16
Transistor symbols. (Courtesy of Chrysler Motors Corp.)

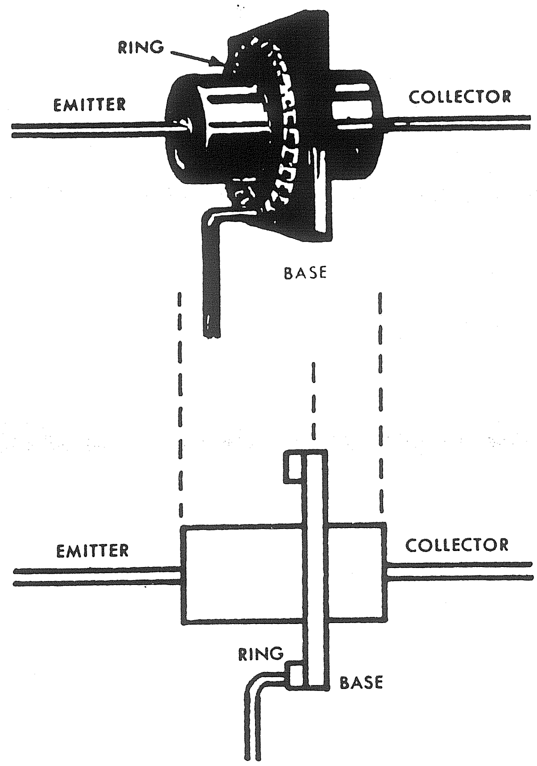


FIGURE 3-17
Design of a conventional transistor. (Courtesy of Delco Remy)

The conventional transistor is encased in a metal container (see Fig. 3-14) that protects it from damage. Also, the container is evacuated to prevent stray molecules of air from entering and interfering with the transistor's operation.

Transistor Operation

The transistor described above is *bipolar* in that the unit uses both holes and electrons as current carriers. In other words, current flows with positive and negative polarity in different circuits. The emitter always supplies the majority current carrier (either electrons or holes), and the collector receives them as long as the transistor is turned on, or conducting.

With this in mind, let's examine the operation of a typical NPN transistor. There are, in fact, two PN junctions, one between the emitter and base and the other between the base and the collector. Therefore, bias voltage can be applied to two different places.

If we apply forward-bias voltage to the emitter-base junction (negative terminal of the battery attached to the N emitter and positive terminal to the P base), a small current flows as within a simple PN

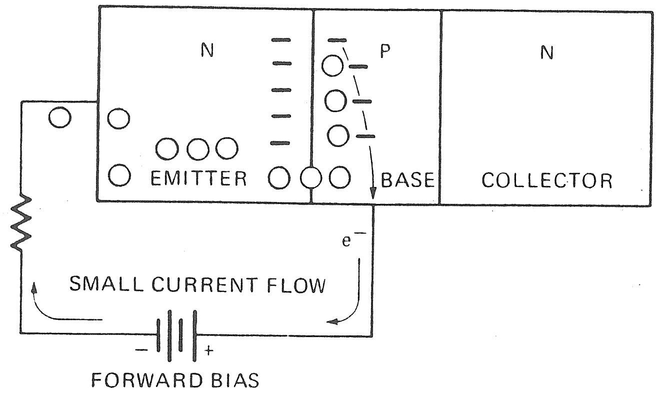


FIGURE 3-18
Forward-bias voltage applied to the emitter-base junction.

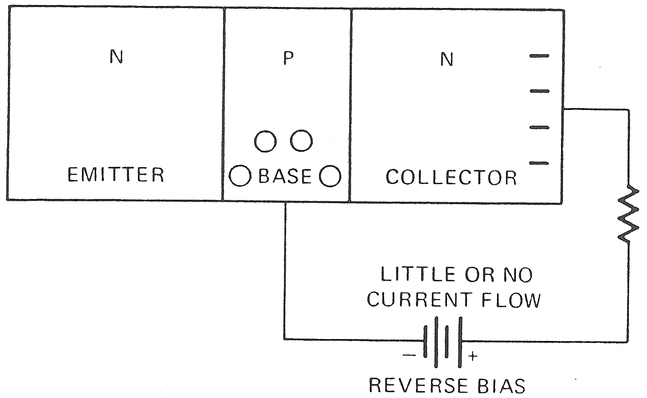


FIGURE 3-19
Reverse-bias voltage applied to the base-collector junction.

diode (Fig. 3-18). Holes move from the P base material toward the negative battery terminal through the N material. Electrons, on the other hand, move from the N material through the P base material to the positive battery terminal. However, excess free electrons do accumulate in the P base material. This is due to the overall reduction in available holes as a result of the doping process.

If we now apply a reverse-bias voltage to the base-collector circuit, current cannot flow (Fig. 3-19). Again, the PN junction acts like a diode with the voltage polarity reversed. In this case, the positive terminal of the battery attracts electrons away from the PN junction, while the negative terminal pulls the holes away from the junction. As a result, no current can flow.

In order to get the transistor to conduct and amplify current, let's assume the N-type emitter is at a zero volt potential. If we apply a low forward-bias voltage of three volts across the emitter-base PN junction, the result will be electron flow from the emitter into the base and hole movement in the opposite direction. Even at the low applied voltage, there are extra electrons that gather in the base. Remember, the base has fewer holes than the emitter due to their different doping ratios.

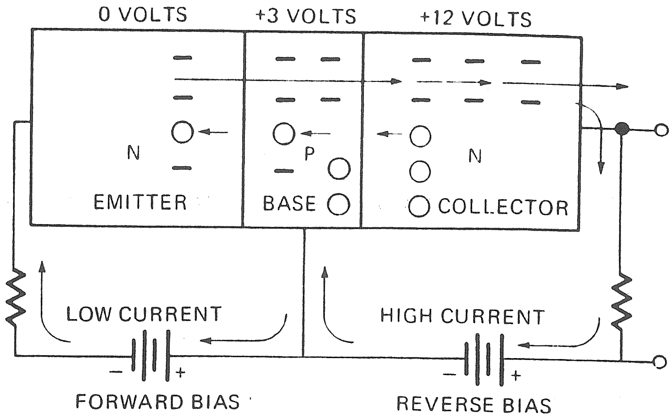


FIGURE 3-20
Small emitter-base current controls a larger flow through the emitter and collector.

Now, let's see what occurs when we apply a higher reverse-bias voltage of 12 volts to the collector (Fig. 3-20). This action causes a reverse bias across the base-collector PN junction. Consequently, high positive voltage on the collector terminal attracts electrons away from the base-collector PN junction, so little or no electrons should actually flow between the base and the collector. However, there is the matter of the extra electrons that have gathered in the base due to the forward-bias voltage on the emitter-base PN junction. They can now pass through the base and into the collector as they move toward the high positive voltage terminal of the battery.

As you can see, by itself, the reverse-bias voltage of 12 volts across the collector-base PN junction would not cause electron flow between the emitter and collector because there is high resistance. Therefore, almost no current flows through the circuit and the transistor is considered off.

But by applying the forward-bias voltage across the emitter-base PN junction, emitter electrons mass in the base and will flow easily into the collector toward the higher positive voltage source. In other words, resistance is reduced and the transistor turns on. The overall electron flow is forward from a low (−) potential at the emitter to a high (+) potential at the collector.

Note: The voltage examples used here are purely arbitrary; the actual applied voltages are a design consideration for each transistor application.

The time required for the emitter-base current to reach the maximum value designed to turn the transistor on is called *saturation.* Depending on design factors, a transistor can turn on and off (go from cutoff to saturation) in less than one millionth of a second.

The example of the NPN transistor shown in Fig. 3-20 clearly points out how the unit controls current flow through its parts and that a small voltage and current flow across one junction can regulate a larger current flow through the entire device. In the PNP transistor, the voltages and flow of electrons and holes are reversed, but the operating principle is the same.

Transistor Gain

The ratio between input and output power is known as *transistor gain* and is a design factor of the unit itself. Suppose, for example, that the forward-bias voltage across the emitter-base PN junction in Fig. 3-20 is supplied by the pickup coil within a distributor. This low voltage and current flow represent a fraction of a watt of electrical power, but are the input power for the transistor.

The larger voltage and current flow between the emitter and collector represent several watts of power, enough to energize the ignition coil. This then is the transistor's output power.

If the input power fluctuates between 1/10 watt and 5/10 watt (100 to 500 milliwatts) and the transistor gain is 100 to 1, the output power between the emitter and collector will fluctuate between 1 watt and 5 watts. This is plenty of power to energize the ignition coil in response to a low input voltage and current flow from the distributor pickup coil.

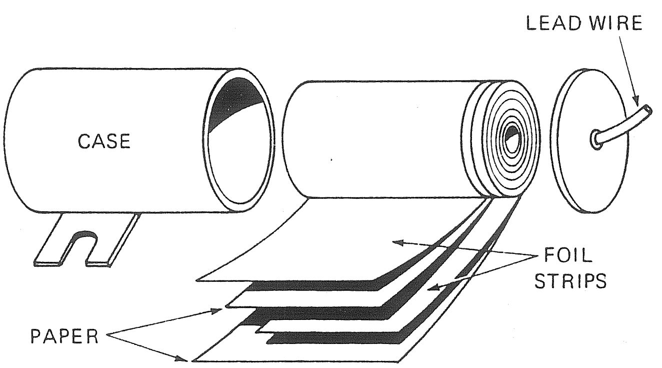


FIGURE 3-21
Design of a fixed capacitor.

3-4 CAPACITORS

Automotive electrical and electronic systems require the use of capacitors. A *capacitor* can serve a number of different functions in either or both types of circuit. For example, a capacitor will store voltage; therefore, it slows down any change in circuit voltage. In a given circuit, capacitors are often used to absorb voltage changes and thus act as shock absorbers. If a high voltage pulse is applied to a circuit, the capacitor absorbs it before the resulting increase in current flow can damage other parts of the circuit.

In addition, a capacitor is used as a short-circuit shunt to cause current flow to stop quickly when a circuit is opened. This is one of the tasks of capacitors that are used in ignition circuits.

Finally, a capacitor can store a high voltage charge and then discharge it quickly when connected across a circuit. In this way, the capacitor holds the charge until it can be transferred to and used by another part of the same or another circuit.

Fixed Capacitor Design

There are two designs of capacitors in use, the fixed and variable. A typical *fixed capacitor* consists of two long conductive foil strips, called plates, usually made of metal such as aluminum, zinc, steel, or copper (Fig. 3-21). Between each foil roll is an insulator. The insulator might be nothing more than the air in the space between the rolls, or it may be some nonconductive material such as mica, ceramic, glass, paper, or plastic. The insulation itself is known as a *dielectric.*

The foil strips and insulators are usually about eight feet in length, and the manufacturer rolls these components into a tight, round, cylinder-shaped bundle. However, during this process, the foil strips are offset so that one edge of one strip protrudes past the insulation on the top end of the assembly, and the edge end of the other plate extends past the insulation on the bottom side.

These exposed edges provide the electrical contact points for the two plates. The manufacturer flattens these edges before installing the roll into the metal housing, or case. With this arrangement, the bottom on the case contacts the foil edge and grounds it. The other foil edge provides the contact point for the insulated lead wire at the top of the case. Finally, to provide additional insulation, wax or oil is drawn into the case, and the entire unit is sealed.

Capacitance

The unit just described has an electrical property known as *capacitance.* Capacitance is the capacity, or ability, of two conducting surfaces to store an electric charge, or voltage, when separated by an insulator. The capacitor has this ability.

Capacitors are also called *condensers.* This term developed because electric charges collect, or condense, on the plates of the capacitor much like water vapor collects and condenses on a cold drinking glass.

The property of capacitance exists due to the electrical principle that unlike charges (+ and −) attract each other. This leads to the assumption that there is a field of electrical energy, or potential voltage, between any two oppositely charged points or surfaces. This is called an *electrostatic field* because the charges do not move. In other words, the charges are stored on the two plates in a form of static electricity.

When a capacitor is connected into an electrical circuit, the plate attached to the lead wire has a positive polarity, or excess of holes (Fig. 3-22). The ground plate has a negative charge, or an excess of electrons. Consequently, an electrostatic field exists between the two plates due to the opposite charges. The field will not be present if the capacitor is disconnected from the electrical circuit. Finally, the capacitance of a fixed condenser is a physical property, and this value will not change in any circuit. However, there are factors that affect its capacitance.

Factors of Capacitance. Capacitance is regulated by three factors. First, the larger the surface area of the plates, the greater the capacitance will be. This is because more electrons and holes can collect on larger plates than smaller ones. Second, the closer the plates are to each other, the greater the capacitance is because a stronger electrostatic field exists between the charged bodies. Third, the insulating qualities of the dielectric affect capacitance. The capacitance of a condenser is higher if the dielectric is a very good insulator.

Fixed Capacitor Ratings. A fixed capacitor (Fig. 3-23) is rated in units called *farads* (F). One farad is a very large charge, and a capacitor rated at one farad may be the size of a hot water heater. A smaller unit, the *microfarad* (μF) is used to describe the electrical capacity of fixed automotive capacitors. A microfarad is one-millionth (0.000001) of a farad.

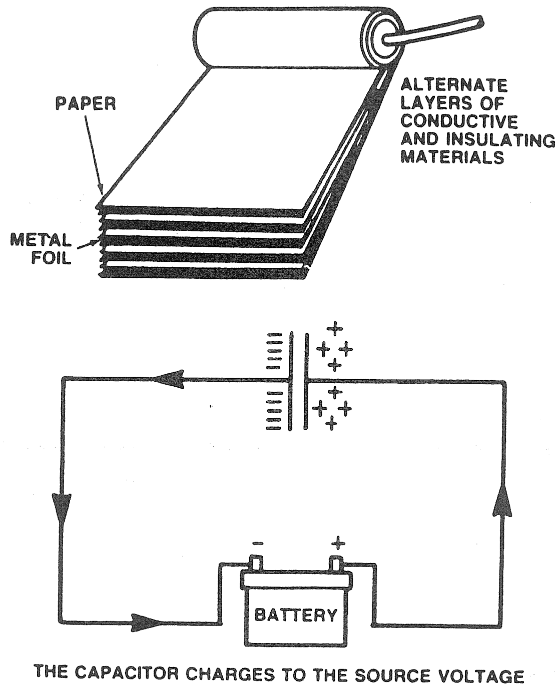


FIGURE 3-22
Capacitor plates charge to the source voltage. (Courtesy of Chrysler Motors Corp.)

Fixed Capacitor Operation. In order to understand the operation of a capacitor, consider the circuit illustrated in Fig. 3-24. Since the capacitor plates are insulated from each other, it would seem that no current will flow in the circuit. This is indeed the case, *except* at the instant of time when the switch is closed. When this occurs, the voltage across the capacitor plates will suddenly change from 0 to 12 volts.

When the switch closes, electrons will leave the battery and congregate on the capacitor's negative plate, as shown. This plate will have an excess of electrons. At the same time, holes will leave the (+) battery post and cause the other capacitor plate to have a positive charge. It is important to note that the electrons and holes flow through the circuit and not through the insulating material separating the two capacitor plates.

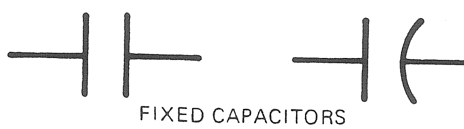


FIGURE 3-23
Symbol for a fixed capacitor.

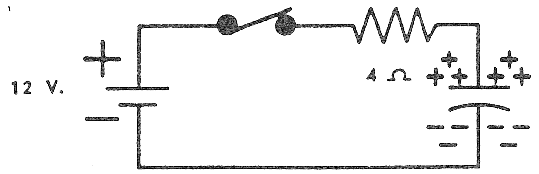


FIGURE 3-24
Capacitor storing a charge. (Courtesy of Delco Remy)

As the two plates become negatively and positively charged, a voltage appears across the capacitor. The voltage is the direct result of the difference in the charges between the two plates. As more and more electrons accumulate on the negative plate and holes on the positive plate, the stored capacitor voltage approaches that of the battery. When stored voltage equals battery voltage, electron flow will stop.

If the switch is suddenly opened, the charge of voltage on the capacitor will remain. The accumulated charge represents stored energy.

Theoretically, a capacitor will hold its charge indefinitely. But actually, the charge slowly leaks off the capacitor through the dielectric. The better the dielectric, the longer the capacitor holds the charge.

By adding another switch to the basic circuit, the voltage stored in the capacitor can be used to send current through a resistance unit (Fig. 3-25). When the new switch is closed, a momentary surge of current flows through the resistance unit. Flow will continue until the voltage across the plates decreases to zero. At this point, the capacitor is completely discharged.

As mentioned, the characteristic of a capacitor to act initially like a short circuit when a sudden difference in circuit voltage is applied across its plates makes it suitable to temporarily store electrical energy that would otherwise damage electrical components. To illustrate this point, consider an ignition circuit (Fig. 3-26) in which a capacitor connects across the distributor contact points.

When the contacts separate, a high voltage is induced in the ignition coil primary winding because

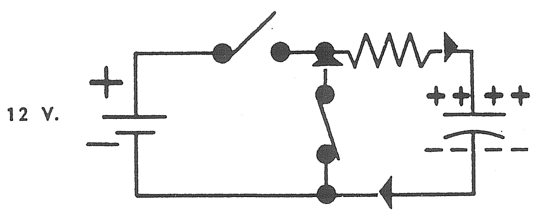


FIGURE 3-25
Capacitor voltage charge used to cause current flow through a resistance unit. (Courtesy of Delco Remy)

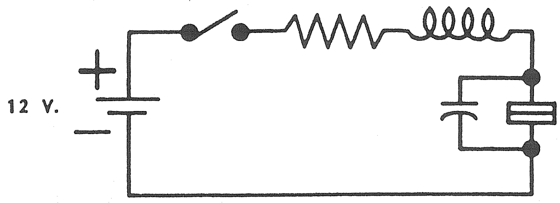


FIGURE 3-26
Ignition capacitor. (Courtesy of Delco Remy)

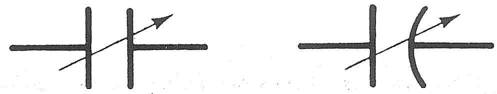


FIGURE 3-27
Symbol of a variable capacitor.

of self-inductance. This high voltage causes the capacitor plates to charge when the contacts first separate. The capacitor, in this manner, acts initially like a short circuit, and current flows into the capacitor to minimize arcing at the contact points.

Variable Capacitors. As mentioned, the fixed capacitor can be used in both electrical and electronic circuits. When used in electronic circuitry, the capacitor is a small ceramic unit with short wire leads that are soldered into a circuit.

Electronic circuitry can also use a *variable capacitor,* one in which its capacitance can be changed (Fig. 3-27). This is usually accomplished by changing or altering the distance between the plate areas.

Figure 3-28 illustrates a special leaf-type adjustable capacitor used exclusively in some electronic circuits. The variable capacitor, in this case, is used to *tune a circuit,* causing it to oscillate or vibrate at a certain frequency. In the example shown, the coil, resistor, and capacitor form what is called a basic *tank circuit*—one that will surge back and forth at a certain frequency if an alternating current signal is impressed across the input leads.

The variable capacitor, or tuner in this case, is charged until the circuit picks up the tiny input signal and begins to oscillate at that frequency. When the right frequency is reached, the circuit will be aided in one direction. Then, when the current stops flowing into the capacitor, it will begin discharging back out into the circuit in the other direction. If the unit is set at the wrong capacitance, the circuit vibrates too fast or too slow, and will be opened by the incoming signal. Circuits of this type are used to detect radio frequency.

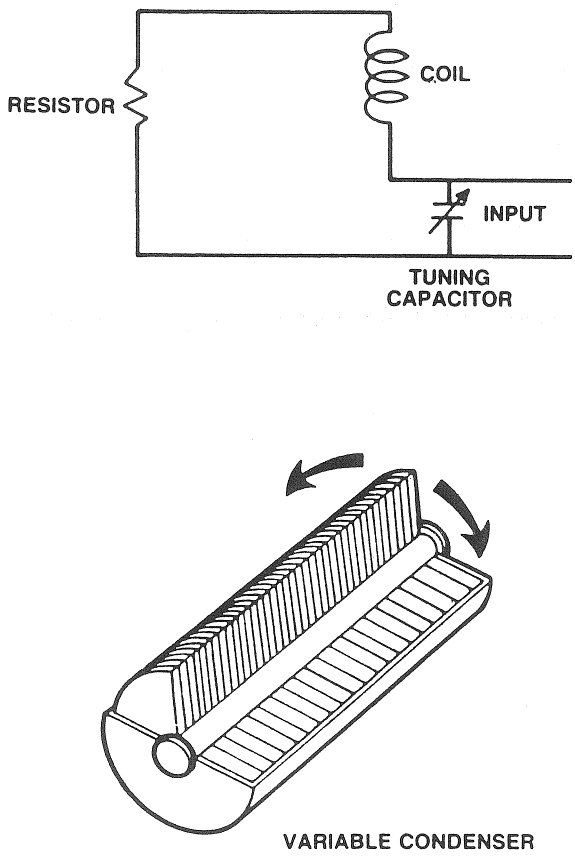


FIGURE 3-28
Variable capacitor and circuit. (Courtesy of Ford Motor Co.)

Printed Circuit Boards

Along with the transistor came another innovation, namely the printed circuit board. A *printed circuit* (PC) board provides a means of securing and connecting solid state electronic component circuits (Fig. 3-29). Due to the smaller component size of transistors, less strength is needed to support them physically and less of a support framework is necessary to contain the average circuit. Therefore, as the components got smaller, the need for a better way to cross-connect them on a chassis became more evident. As a result, the printed circuit started appearing wherever transistors were being used.

The typical circuit board is made of an insulating material. The underside of a board contains an etched conductor, which connects the various terminals of the electronic components into the circuits. The circuits represent a map of conductors, flowing from component to component just as wire conductors do. The components are attached to the board terminal connectors soldered to the etched conductors at appropriate locations.

Rigid circuit boards are used in such components as ignition modules, voltage regulators, and microcomputers. Another type of printed circuit, a flexible, flat-conductor version, is used on many instrument panels.

Note: Printed circuit boards must be handled with care to avoid bending or physically damaging them. A loose electronic component or a cracked or damaged board will result in a nonfunctioning electrical circuit.

3-5 INTEGRATED CIRCUITS

The electronic devices presented so far have been individual components. Engineers classify these as *discrete devices* because each one is made separately with wire leads for connecting it into a given circuit. Most of the early solid state devices were of the discrete type, such as those used in alternator installations. A number of discrete devices are still used in many automobile systems, especially in the ignition, charging, and headlight circuits that require large amounts of electrical power.

While these discrete devices are quite small, they are enormous compared to the modern, sophisticated integrated circuit. An *integrated circuit* (IC) is a very complex electronic circuit that can contain thousands of transistors and other devices. These are all formed on a tiny ¼-by-¼-inch chip of silicon that is about the thickness of a thumbnail. Consequently, the circuits and electronic devices are usually so small they cannot be examined without the help of a microscope (Fig. 3-30).

Through the use of IC chips, the size and power requirements of electronic components have been drastically reduced. Moreover, the reliability of integrated circuits is much greater than any other type of electronic construction.

Although integrated circuits were expensive to produce in the 1960s and early 1970s, their cost is now only a fraction of what it was then. This is the result of improvements made in construction and mass production processes. Finally, integrated circuits are found in automotive electronic voltage regulators, ignition modules, microcomputers, instrument clusters, and voice alert and navigation systems.

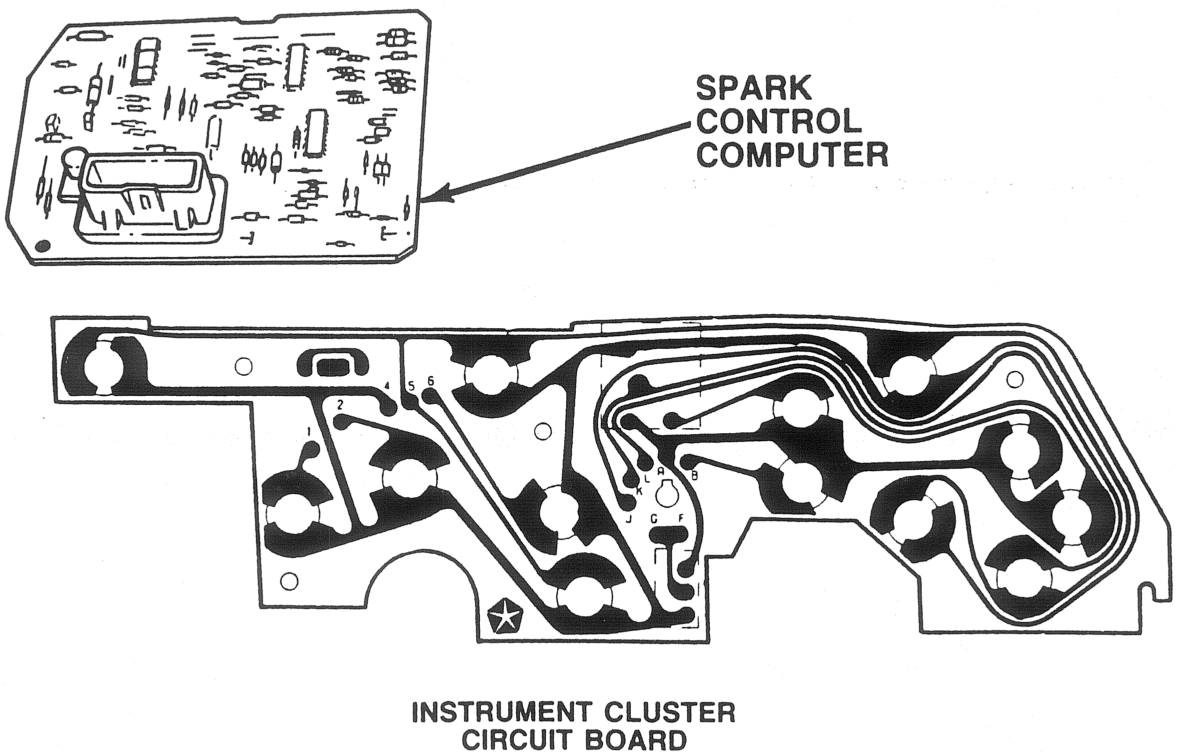


FIGURE 3-29
Typical circuit boards. (Courtesy of Chrysler Motors Corp.)

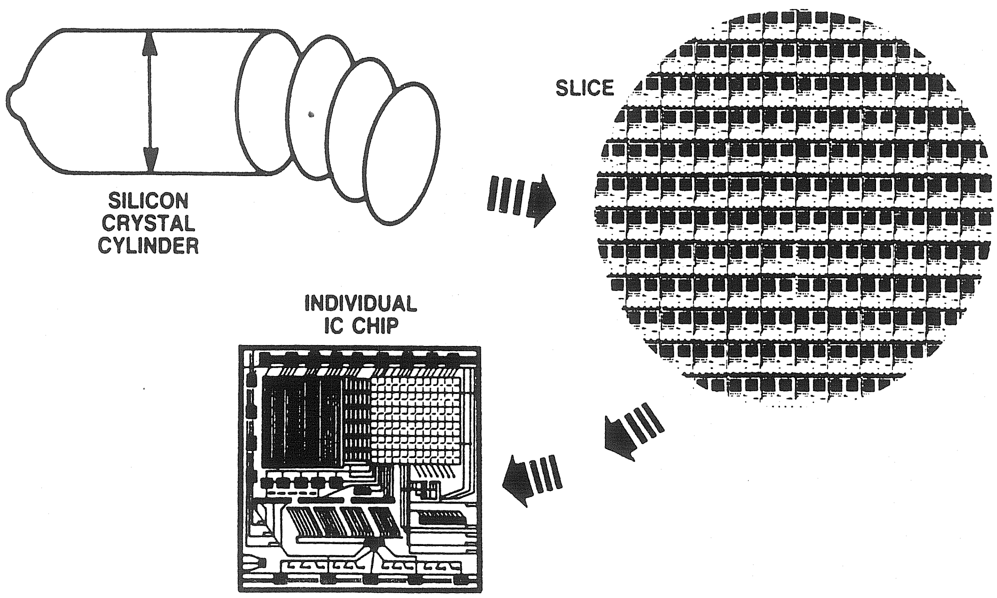


FIGURE 3-30
Individual IC chip. (Courtesy of Chrysler Motors Corp.)

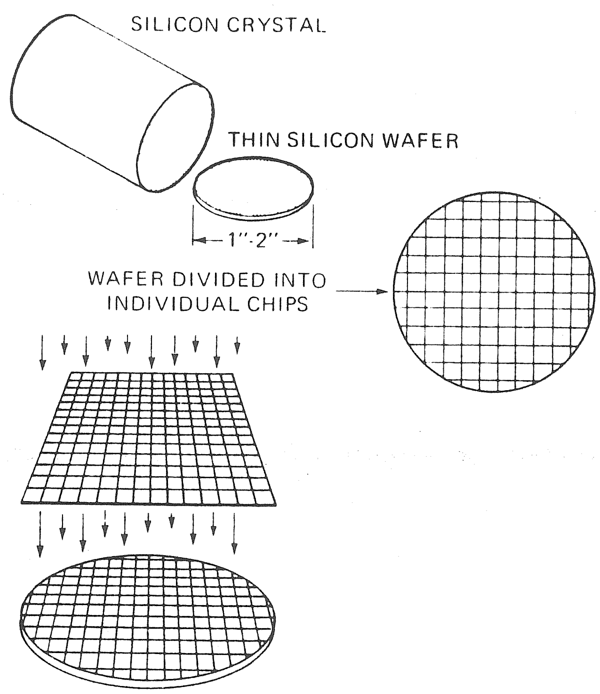


FIGURE 3-31
Cutting and screening the wafer.

Typical Manufacturing Process

Integrated circuits are made by photochemically etching circuit patterns on a silicon wafer and then depositing various conductive and insulating materials through a diffusion process. This actual procedure often requires more than 100 separate steps. However, the following is a simplified version of the process to provide you with a basic idea of how it is done.

To begin with, a silicon crystal of the desired type is grown in a very special environment. For our purposes, the crystal is the P-type and will be used to develop a high speed N-MOS chip.

After a one-inch to two-inch wafer is sliced off, its surface is divided into separate areas, each of which will be a separate chip (Fig. 3-31). This way, 25 or more chips can be made at the same time on a two-inch slice. Next begins a number of steps that involve using a screen or mask to control the etching process and the application of chemical and gases to the surface of the silicon wafer.

To illustrate the first part of this process, examine Fig. 3-32. In this diagram, you see the chip area for a single N-MOS transistor located on the wafer. Diagram (a) shows a cross section of the P-type silicon wafer as it appears after being sliced off

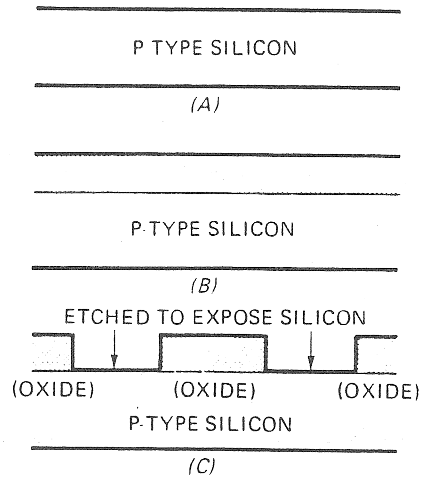


FIGURE 3-32
Forming the drain and source areas of the transistor.

the roll. Diagram (b) illustrates its appearance after the application of an oxide layer to one surface of the wafer. Diagram (c) shows the use of masks to photochemically etch the oxide to remove places on it that will become the drain (collector) and source (emitter) of the transistor.

The exposed areas are now treated with a gas mixture of atoms and subjected to a high temperature. This process changes the makeup of these areas into N-types within the P-type structure (Fig. 3-33a).

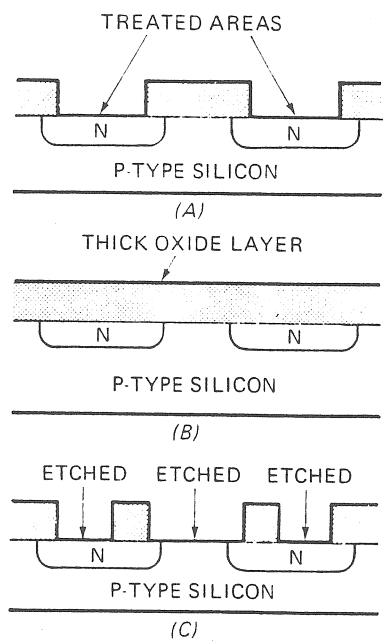


FIGURE 3-33
Creating the N-type areas in the P structure.

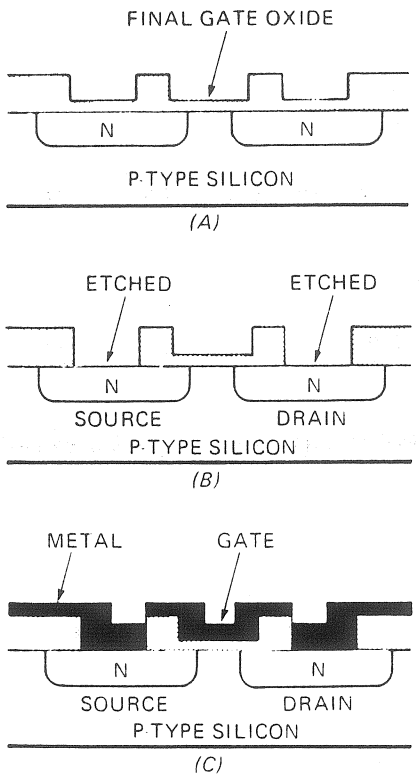


FIGURE 3-34
Completing the source, drain, and gate areas.

A thick oxide layer is then applied quickly to stabilize the entire surface area and protect it from contamination (Fig. 3-33b). This process is going on in every location and on every chip on the entire wafer.

For a second time, the oxide layer is selectively etched away (Fig. 3-33c). This action exposes the N areas and the area between them.

Oxide is once again applied quickly, but in a thinner layer (Fig. 3-34a). This coating is necessary to seal the area under the gate only. However, one area cannot be coated without layering the others as well. The next step is to etch away the oxide for the last time, exposing the N areas (Fig. 3-34b).

As a final step, metal contact material is applied to the N areas and the gate (Fig. 3-34c). Notice in diagram (c) that neither the source nor the drain contact material touch the gate.

Operation of an IC Transistor

Now that we have a completed IC transistor, let's see how it operates (Fig. 3-35). In order for electrons to flow between the source and the drain, a positive charge must be applied to the gate directly over the

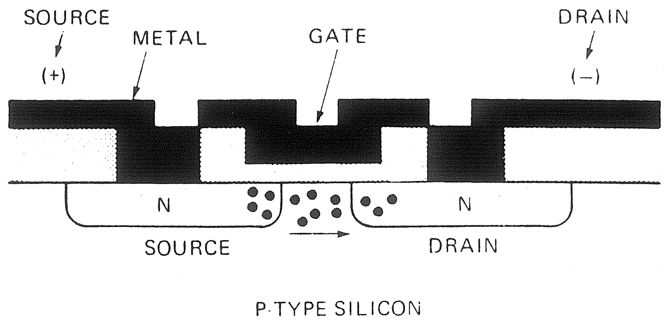


FIGURE 3-35
Operation of an IC transistor.

space shown. With the positive charge applied, electrons mass at the gap between the source and the drain. Current flows between the two, toward the positive charge at the drain.

Memory Cells

A *memory cell* is a device designed to store information electronically. Figure 3-36 illustrates a memory cell that has many of the same features as the IC transistor just discussed. The one main difference is that the memory cell has a floating gate.

If a small positive voltage is applied to the memory cell drain and a large positive charge to the control gate, electrons will be drawn up into the floating gate as shown in the example. The presence of these gate electrons represents either an off (0) or on (1) signal.

The floating gate electrons remain in place even after the power is turned off. In other words, the cell remembers the signal. The cell is erased by applying a large negative charge to the control gate and a small positive voltage to the drain.

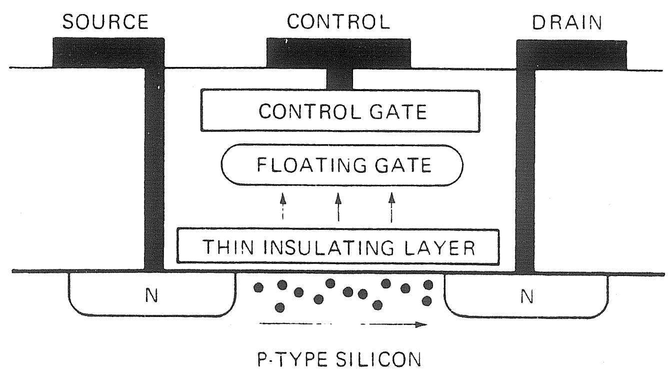


FIGURE 3-36
Memory cell design.

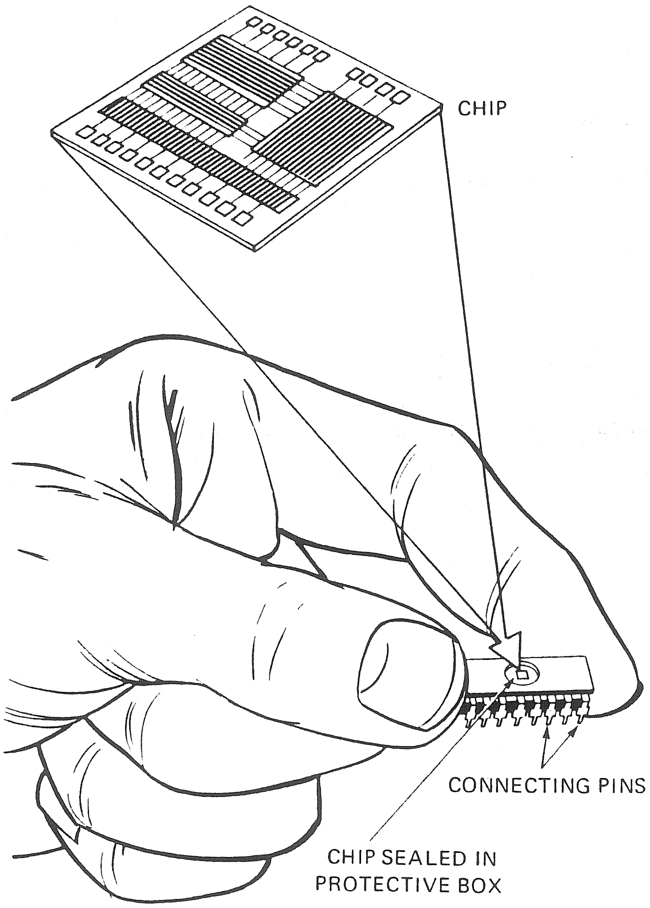


FIGURE 3-37
Typical IC package installation.

Typical IC Installation

After the IC is formed, it is installed into a package device similar to the one shown in Fig. 3-37. The protective box has rows of small metal connecting pins along its edges. These provide the electrical connections when the assembly is plugged into a larger circuit.

If an IC is combined in a package with one or more discrete devices, the result is a *hybrid circuit.* Many automobile systems have used and continue to use this kind of circuit. But as more and more functions are packed into a single IC, the need for discrete diodes, resistors, and capacitors is decreasing.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. What is the difference between a circuit with a discrete device and the IC [3-5]?

2. In relation to semiconductors, what is covalent bonding [3-1]?

3. Explain the functions of a capacitor [3-4].

4. Describe what is meant by forward and reverse biasing [3-2].

5. Explain the functions of a transistor [3-3].

REVIEW

1. What is the name for the electonic device that can store information [3-5]?
   a. memory cell
   b. IC transistor
   c. capacitor
   d. transducer

2. What is the term used to designate the semiconductor doping material [3-1]?
   a. dielectric
   b. impurity
   c. bonding agent
   d. covalent material

3. Leaf-type capacitors are found in what type of circuit [3-5]?
   a. electric
   b. electronic
   c. hydraulic/electric
   d. hydraulic/electronic

4. The movement of holes in a semiconductor can be compared to what type of current flow [3-1]?
   a. conventional
   b. electron
   c. forced
   d. magnetic

5. How many transistors can be formed on a single IC chip [3-5]?
   a. one
   b. five
   c. ten
   d. more than ten

6. An N material has less [3-1]
   a. electrons.
   b. holes.
   c. protons.
   d. neutrons.

7. The ability of a device to store an electrical charge is called [3-4]
   a. voltage.
   b. capacitance.
   c. current.
   d. charging.

8. What is the name given an electronic check valve [3-2]?
   a. memory cell
   b. LED
   c. transistor
   d. diode

9. What is placed between the plates of a capacitor [3-4]?
   a. insulator
   b. dielectric
   c. both a and b
   d. neither a nor b

10. A diode contains what type(s) of semiconductor material [3-2]?
    a. N-type
    b. P-type
    c. both a and b
    d. neither a nor b

11. What is transistor gain [3-3]?
    a. the ratio between input and output power
    b. the ratio between the number of different current carriers in the material
    c. the ratio between base and emitter power
    d. the ratio between base and collector power

12. If a diode is forward biased, what is the direction of hole flow [3-2]?
    a. $-$ to $+$
    b. $+$ to $-$
    c. either a or b
    d. neither a nor b

13. What portion of a transistor is used to turn the device on and off [3-3]?
    a. collector
    b. emitter
    c. base
    d. both a and b

14. A transistor is made from what type(s) of semiconductor material [3-3]?
    a. two layers of P and one of N
    b. two layers of N and one of P
    c. both a and b
    d. neither a nor b

15. A zener diode controls electron flow in how many directions [3-2]?
    a. one
    b. three
    c. four
    d. two

Chapter 4

AUTOMOTIVE MICROCOMPUTERS

OBJECTIVES

After reading and studying this chapter, you will be able to

- describe the function and basic design of a microcomputer.
- explain the difference between analog and digital input signals.
- describe the design and operation of a potentiometer, thermistor, and voltage-generating input sensors.
- explain how analog signals are converted to digital.
- describe the three types of computer memory.
- explain the function and design of computer output devices.
- describe how a microcomputer controls both open and closed loop engine operation.

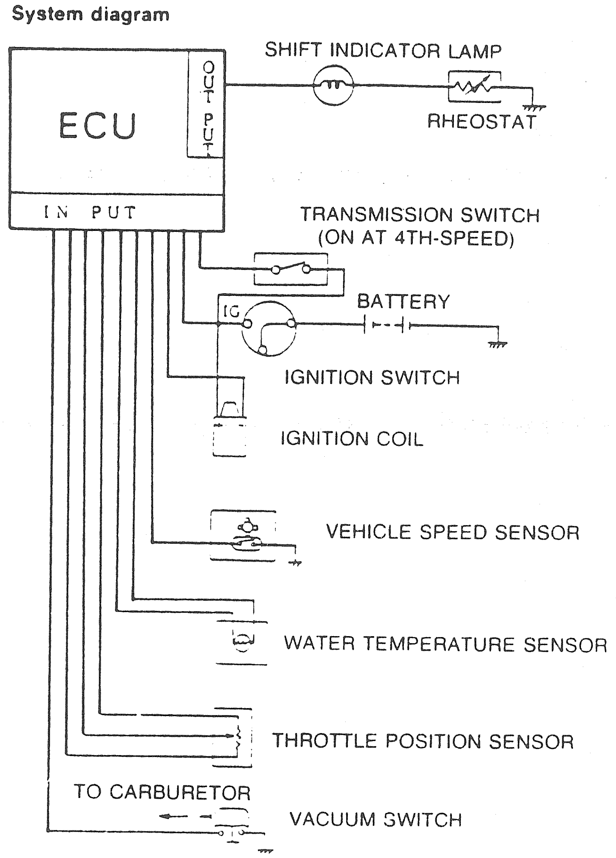


FIGURE 4-3
A number of sensors and switches provide input signals to the microcomputer. (Courtesy of Chrysler Motors Corp.)

4-2 MICROCOMPUTER INPUT SIGNALS

In order for the engine control microcomputer to perform its function, it has to receive a number of input signals from sensors and switches (Fig. 4-3). These signals provide information that the microcomputer will use in its decision-making process. The signals can be either analog or digital, both of which have distinct characteristics.

Analog Signals

An *analog signal* is one that varies continuously. This means that the signal can be any voltage within a given range. In other words, at any point in time, the voltage value of the analog signal may be high, low, or any value in between. In an engine control system, the analog signal provides information to the microcomputer about an operating condition that is constantly changing over a certain range.

Figure 4-4 illustrates an example of an analog signal. The signal begins at 0 volts and then increases toward +5 volts. After reaching a maximum of +5 volts, the signal begins to decrease until it drops to 0 volts again. By graphing the change in voltage, a *DC analog waveform* is created.

Most automotive sensors produce a DC analog waveform. The only exception to this is a magnetic sensor such as a distributor pickup coil. It produces an *AC analog waveform* (Fig. 4-5). In this situation, voltage is induced in the pickup coil first toward the positive and then toward the negative end, as shown.

Digital Signals

A *digital signal* is one that has only two values. That is, the voltage is either on or off (Fig. 4-6). The graph in the illustration shows how the voltage values change as the switch is operated. The graph begins with the signal off, which indicates the voltage is at 0 volts.

When the switch turns the signal on, the graph shows the voltage value increase to 5 volts. But note that the change from 0 volts to 5 volts is very abrupt. Turning the switch off again causes an abrupt drop in voltage from 5 volts to 0 volts.

Thus, by graphing the changes in voltage, the *DC digital waveform* is created. Because of the abrupt changes in voltage, the final waveform has sharp corners and looks like a square. For this rea-

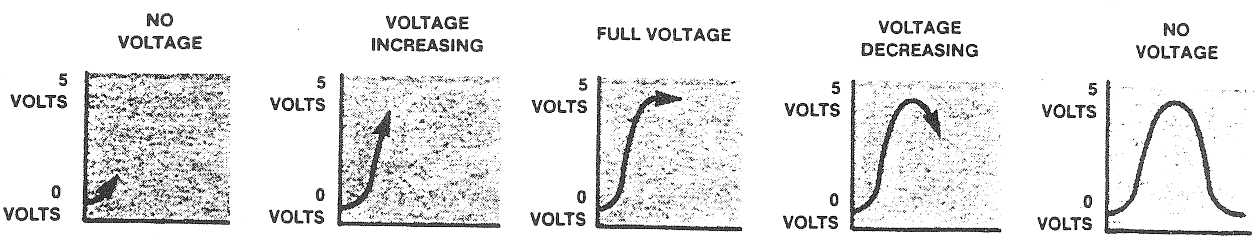


FIGURE 4-4
DC analog signal. (Courtesy of Ford Motor Co.)

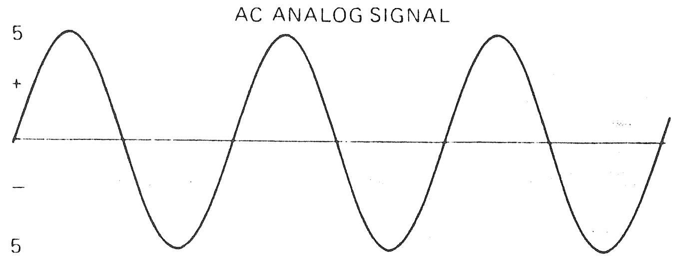


FIGURE 4-5
AC analog signal.

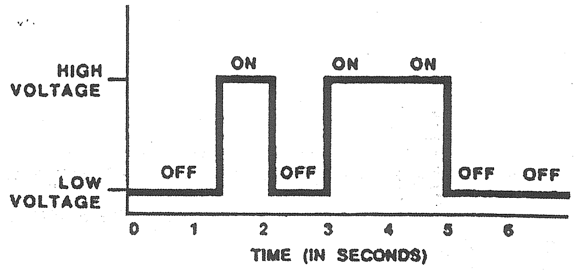


FIGURE 4-7
Typical digital waveform. (Courtesy of Ford Motor Co.)

son, this type of waveform is also called a *square wave*.

By turning a switch either on or off rapidly, the waveform of the signal produced begins to look like the one illustrated in Fig. 4-7. Notice that the switch is off for slightly over the first second, on for part of the second, and off a portion of the third. But during the fourth and fifth seconds, the switch remains on; and for the sixth and seventh seconds, the switch is turned off.

The only engine sensor that can by itself produce a digital signal is one that uses a Hall-effect switch, such as Ford's profile ignition pickup (PIP). However, microcomputer integrated circuitry actually consists of thousands of tiny switches. As these are turned on and off, they can produce waveforms that are similar to the one shown in Fig. 4-7.

Binary Code

Because a digital signal varies between two values, the state of the signal can be described as being either on or off, or the voltage can be described as either high or low. Moreover, digital signals can be assigned a numeric value. For example, a signal that is on can be represented by 1 (one) and an off signal by 0 (zero).

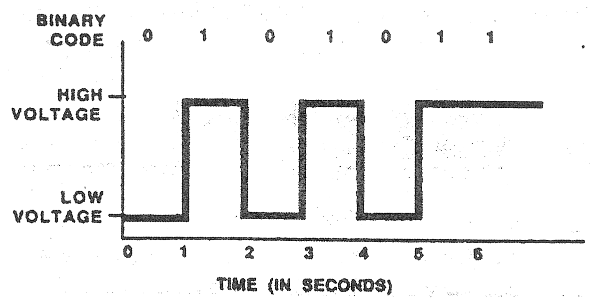


FIGURE 4-8
Binary code. (Courtesy of Ford Motor Co.)

This system of assigning a numeric value to voltage signals is known as *binary coding* (Fig. 4-8). The word *binary* means two values. The two values in the binary code system are 1 and 0.

Furthermore, each 0 and each 1 is known as a *BIT* of information from the term *binary digit*. Eight bits together are known as a *BYTE*, which forms a word in computer language. A word, therefore, contains any combination of eight binary code bits: eight 1s, or five 1s and three 0s, or two 1s and six 0s, and so on.

Binary code is used inside a microcomputer and between it and any electronic device that under-

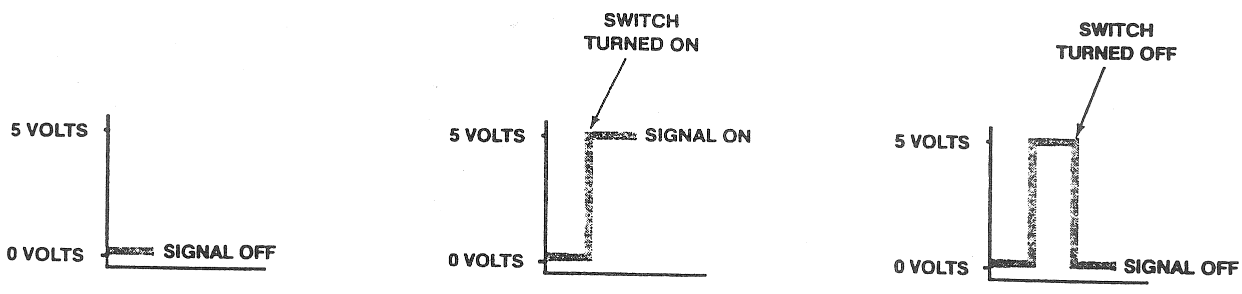


FIGURE 4-6
DC digital signal. (Courtesy of Ford Motor Co.)

stands binary code. Letters, numbers, and conditions are then represented in this binary code by a given series of 1s and 0s, and then transmitted as such. By stringing together thousands of bits, microcomputers can communicate and store an infinite variety of information. Therefore, any data that can be represented in binary code can be processed by the microcomputer.

Since the microcomputer is very good at working with numbers, it is able to perform calculations at an extremely rapid rate. Information is transmitted in binary code by switching voltage on and off at a very rapid rate (i.e., thousands of times per second).

4-3 MICROCOMPUTER INPUT SIGNAL SOURCES

As mentioned, in order for a microcomputer to perform its function, it must have input information. Sensors in an engine control system provide this input. Automotive engine sensors are typed by the manner in which they relay input signals to the microcomputer. The most common types of sensors are the potentiometer, switch, thermistor, detonation, and voltage-generating.

Reference Voltage

Before discussing sensors, it is important to understand what reference voltage is and how it is produced. *Reference voltage* is a constant voltage that is supplied by the microcomputer to some of the sensors. These sensors must have this reference voltage in order to produce an input signal. The sensor types that use reference voltage are the potentiometer, switch, and thermistor.

A voltage regulator inside the microcomputer supplies the reference voltage (VREF) of between 5 volts and 9 volts to these sensors (Fig. 4-9). The sensors, in turn, change the voltage level in proportion to some factor relating to engine operation. The resulting input signal is then relayed back to the microcomputer for processing.

Potentiometer

The *potentiometer* is a sensor that converts mechanical motion to a voltage value. The potentiometer is used to signal the position of such components as the throttle and exhaust gas recirculation (EGR) valves or the movement of a diaphragm operated by atmospheric pressure or a vacuum.

Typical potentiometer-type sensors in use in engine control systems are the throttle position sensor (TPS), vane airflow sensor, and EGR valve position sensor.

The typical potentiometer-type TPS consists of a resistance material, wiper, and three connectors. Full reference voltage is supplied to the first connector, which is located on one end of the resistance material. The second connector provides a signal return (ground) for the resistor through the processor. The third signal voltage connector is located on the end of the wiper arm (see Fig. 4-9). The tip of the wiper contacts the resistor material.

As the wiper arm moves along the resistance material in response to changes in throttle valve angle, the voltage at the signal connector will increase or decrease. For instance, with the throttle plate fully open (i.e., at 80 to 85 degrees) the voltage signal to the processor is nearly 5 volts, or reference voltage (Fig. 4-10). However, as the throttle plate closes (angle decreases), the signal voltage drops until it reaches about 0.5 volt at closed throttle (i.e., a 0 degree angle).

In the throttle position sensor and in the other potentiometer-type units, the signal voltage increases or decreases by changing the resistance between the reference voltage connector and the wiper arm connector. With the throttle plate fully open, for example, the wiper assumes a position on the resistor that produces the least amount of resistance between the two connectors. At closed throttle, on the other hand, there is maximum resistance between the two connectors. The total resistance then changes between the two points as the wiper moves along the resistor.

Switches

A switch is also frequently used to signal the microcomputer, indicating the position of a component. However, in this case the signal voltage has only two values, high and zero, indicating that the switch is either closed or open.

Typical examples of switches used for this purpose include the neutral safety switch, the brake on/off switch, the clutch engaged switch, the key-on switch, and the air conditioning clutch switch.

Figure 4-11 illustrates a typical circuit of a switch-type sensor, a clutch engaged switch (CES). In this installation, an electrically conductive blade moves between two contacts. When the switch is

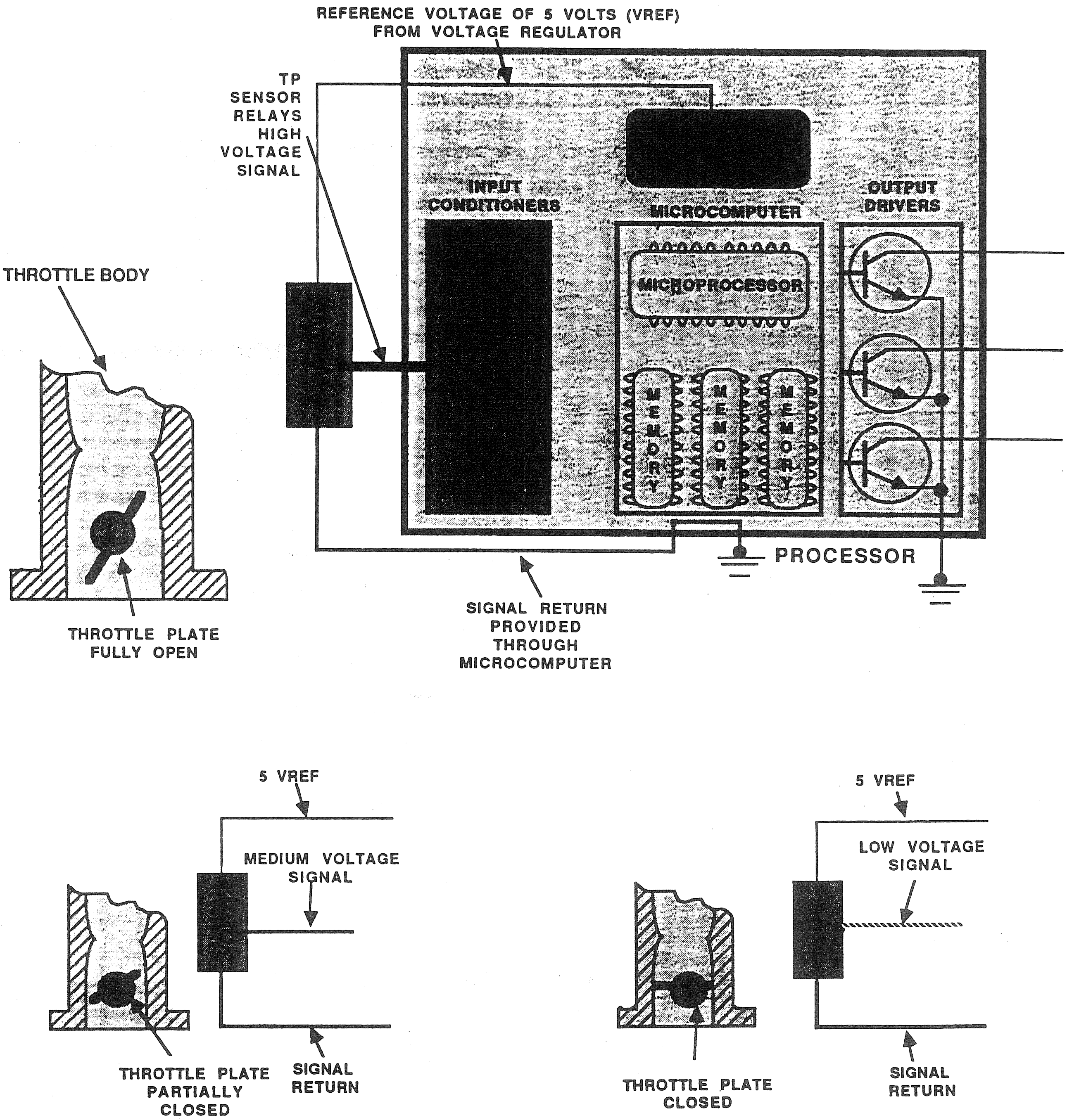


FIGURE 4-9
Schematic of the reference voltage source and a throttle position sensor. (Courtesy of Ford Motor Co.)

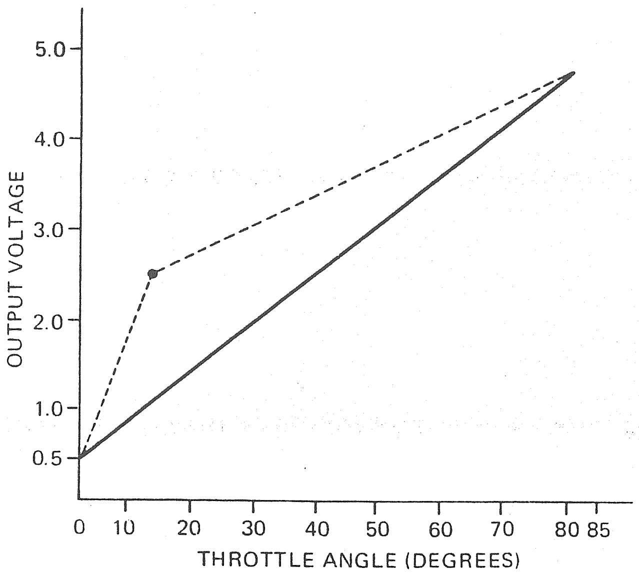


FIGURE 4–10
TPS voltage curve.

closed, the blade touches both contacts and current flows through the switch. In this case, the signal voltage to the microcomputer will be less than one volt because current flows through the switch to ground at the processor.

When the clutch pedal is released, the CES switch opens, as shown in Fig. 4-11. In this case, current cannot flow through the switch to the processor ground. Consequently, current flows through the signal voltage connector at a potential of nearly five volts.

Thermistors

A *thermistor-type sensor* is a device that converts temperature into a voltage signal. That is, the unit develops a voltage signal in proportion to changes in temperature. A thermistor device is made of a semiconductor material, the resistance of which varies as its temperature increases or decreases. In other words, the thermistor is a form of variable resistor. As shown by the curve in Fig. 4-12, the resistance of the thermistor decreases as its temperature goes up. Conversely, its resistance increases as the temperature decreases.

A thermistor-type sensor is therefore used to measure such things as engine coolant, air cleaner, intake manifold, or passenger compartment temperatures. Typical thermistor-type sensors are used in computerized engine control systems to measure engine coolant temperature, charge temperature, and vane air temperature.

Figure 4-13 is a schematic of an engine coolant temperature (ECT) sensor circuit. Notice the ECT is represented on the diagram by the variable resistor symbol. Moreover, like any type of thermistor, the ECT has two connections. The top connection provides the reference voltage from the processor; a ground circuit is provided through the processor via the lower connector.

A special signal line branches off the reference voltage line to provide the ECT input signal back to the processor. As the resistance of the thermistor

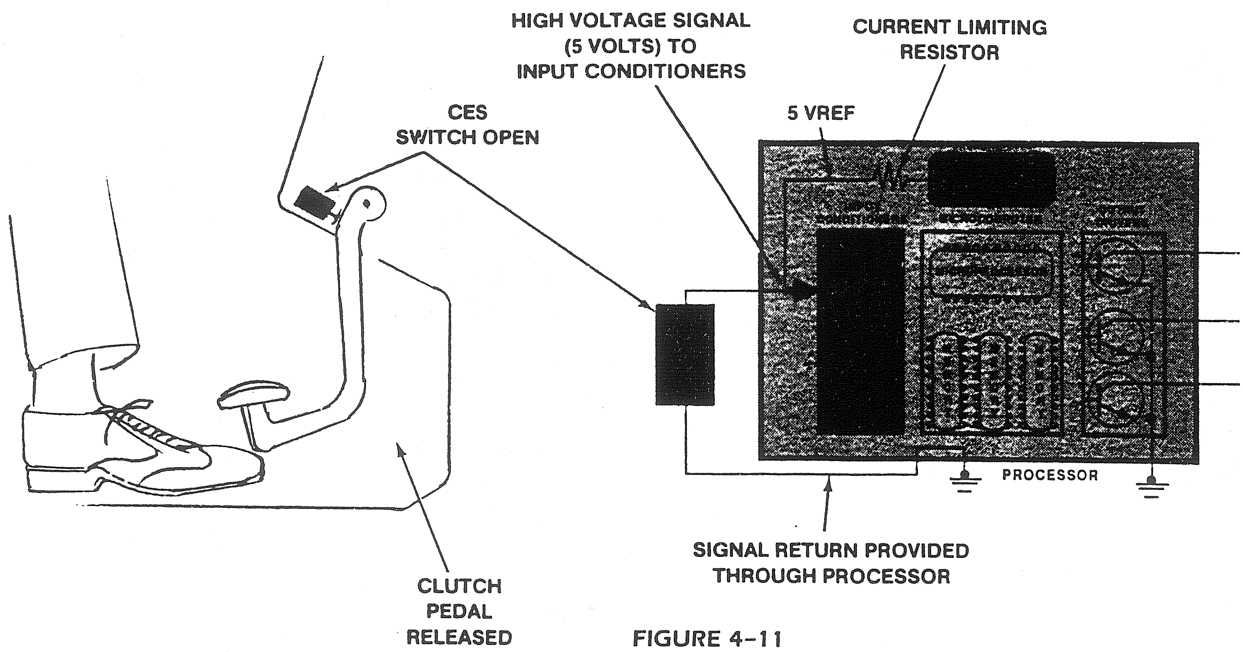


FIGURE 4–11
Typical switch schematic. (Courtesy of Ford Motor Co.)

increases or decreases, this input signal changes. The microcomputer then uses this voltage signal to determine changes in engine temperature.

When the engine is cold, the resistance of the ECT sensor is high (see Fig. 4-13). As a result, a high voltage input signal is routed back to the processor. But as engine temperature increases, the resistance of the ECT sensor decreases, and more current flows through the sensor to ground. This action decreases the ECT input signal to the processor (Fig. 4-14).

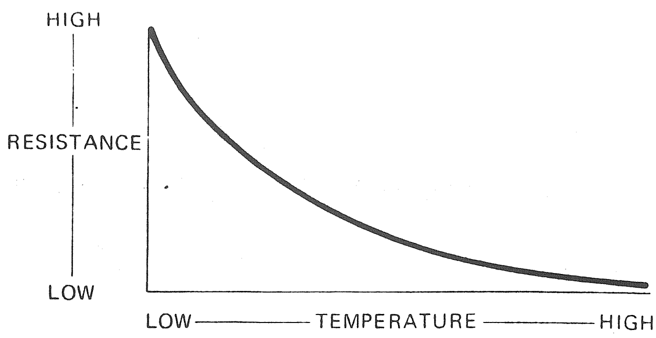


FIGURE 4-12
Thermistor temperature versus resistance curve.

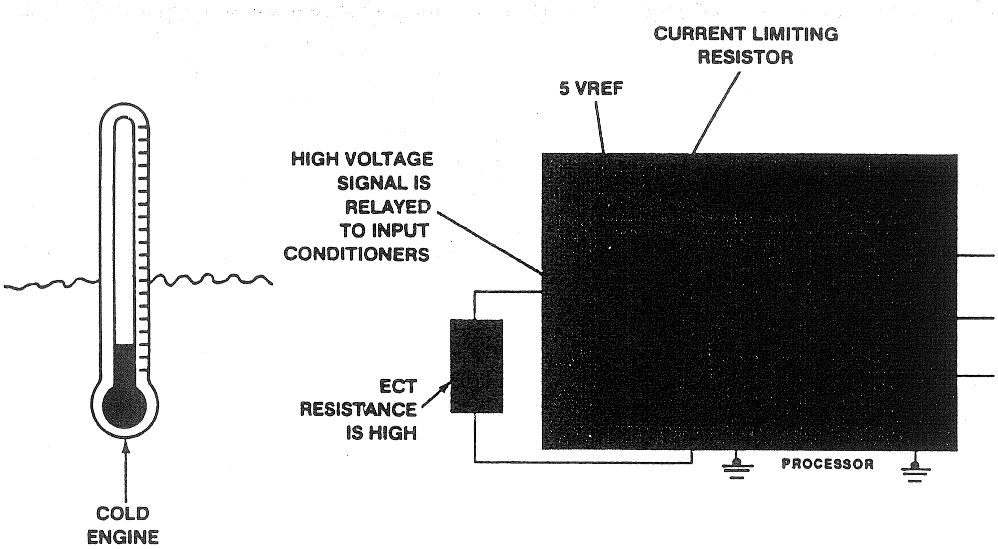


FIGURE 4-13
Typical engine coolant temperature (ECT) circuit with the engine cold. (Courtesy of Ford Motor Co.)

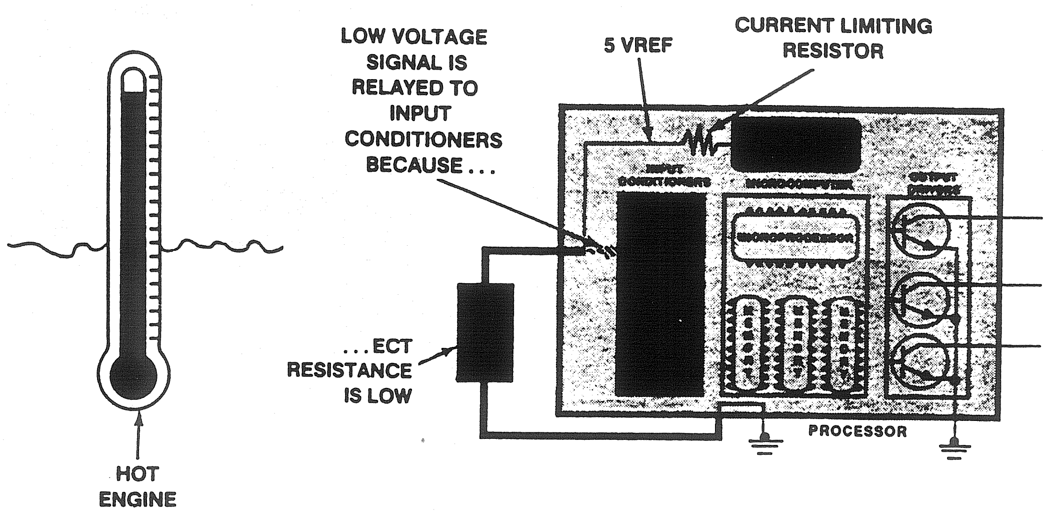


FIGURE 4-14
Typical ECT circuit with the engine hot. (Courtesy of Ford Motor Co.)

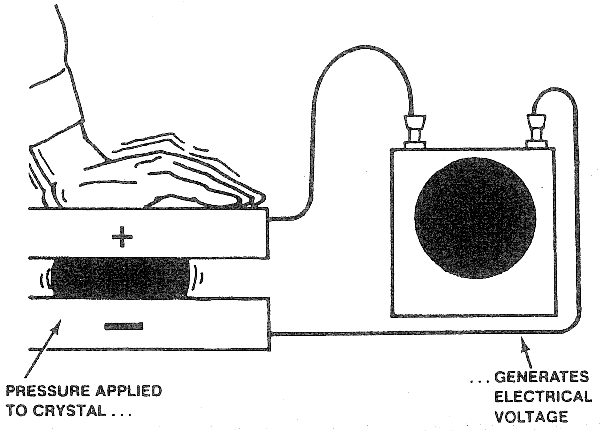


FIGURE 4-15
Design and operation of a piezo-electric sensor. (Courtesy of Ford Motor Co.)

Voltage-Generating Sensors

A *voltage-generating sensor* is not supplied with a reference voltage. Instead, the sensor generates its own signal for use by the processor. This type of sensor uses a variety of means to create the input voltage signal. In some of these sensors, a certain type of quartz crystal is used to generate voltage. Others utilize electrically conductive materials or electromagnetic principles to generate the voltage.

The types of devices that are voltage generating include the detonation sensor, exhaust gas oxygen sensor, distributor magnetic pickup sensor, and Hall-effect switch.

Detonation Sensors

A *detonation sensor* is a *piezo-electric device* that converts vibration or motion into an electrical voltage. This type of sensor is commonly used to monitor the vibrations resulting from engine detonation, or spark knock.

A typical piezo-electric sensor consists of a special quartz crystal sandwiched between two electrically conductive electrodes (Fig. 4-15). As pressure is applied to the crystal, a voltage is generated between the two electrodes.

Figure 4-16 illustrates this device as it appears in a schematic of a detonation or knock sensor. The knock sensor threads into the engine block or intake manifold where it can detect engine vibrations. (The engine block or intake manifold also forms the sensor ground return circuit.) The voltage signals produced by the sensor as a result of these vibrations are then relayed back to the processor in the form of voltage signals.

The typical engine produces many kinds of vibrations during normal engine operation. For this

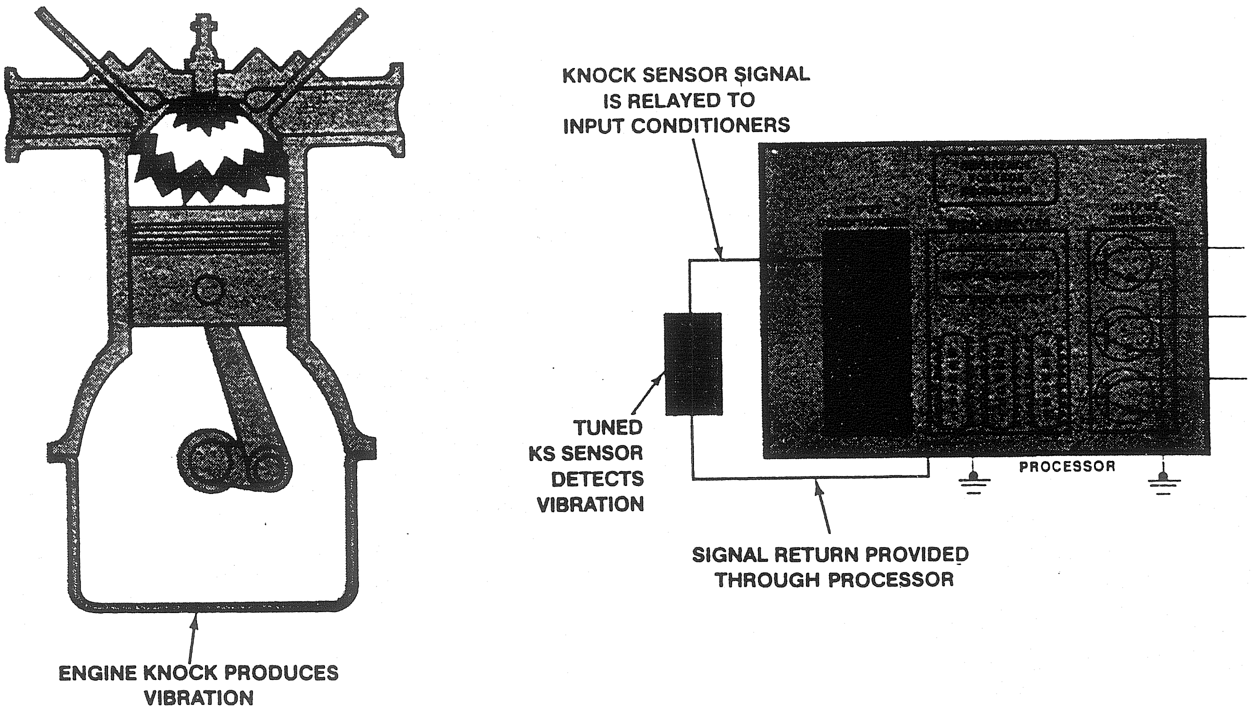


FIGURE 4-16
Typical detonation sensor circuit. (Courtesy of Ford Motor Co.)

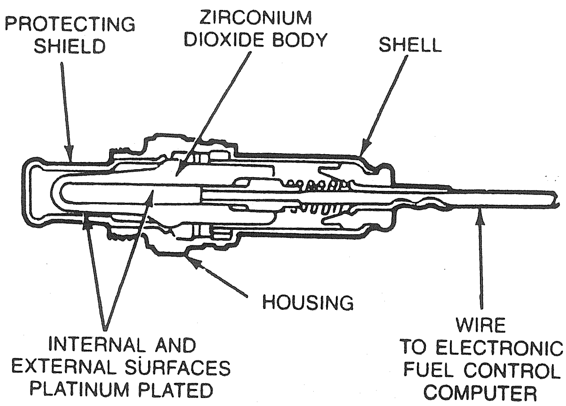


FIGURE 4-17
Typical oxygen sensor. (Courtesy of Chrysler Motors Corp.)

reason, a knock sensor is tuned to respond only to the type of vibrations produced by detonation.

In operation, the vibrations are transmitted via the engine block or intake manifold to the knock sensor where they place pressure on the quartz crystal inside the sensor. This results in a voltage signal that is passed back to the processor as input. The more severe the vibrations, the higher the voltage signal will be.

Exhaust Gas Oxygen Sensor

The *exhaust gas oxygen sensor* develops a voltage signal based on the amount of oxygen present in the exhaust gases (Fig. 4-17). The resulting input signal is used by the microcomputer to determine an engine's air/fuel ratio.

The exhaust gas oxygen sensor typically threads into the exhaust manifold that also forms the ground side of its circuit. The sensor detects the presence of oxygen in the exhaust gases and then produces a variable voltage, according to the amount that is present at any given time. A high concentration of oxygen (lean air/fuel ratio) in the exhaust causes the sensor to produce a low voltage signal (Fig. 4-18). On the other hand, a low concentration of oxygen (rich air/fuel mixture) produces a high voltage signal.

Figure 4-19 illustrates the construction of a typical oxygen sensor. A zirconium dioxide thimble is located in the tip of the sensor, as shown. Exhaust gases can enter the tip through slots, and air can pass into the body of the sensor through an air intake opening. This design permits exhaust gas to contact the outside of the thimble while air touches its inside surface.

Both the inside and outside surfaces of the

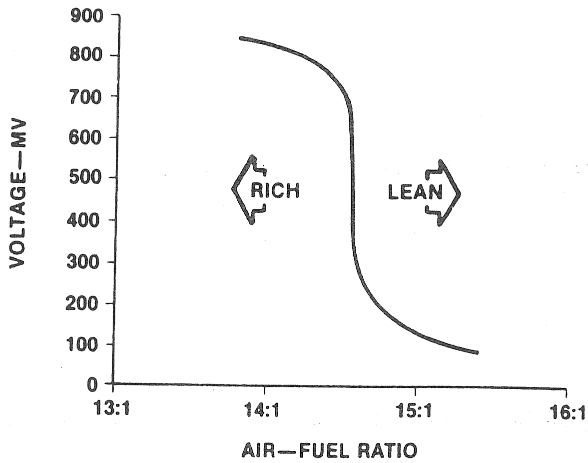


FIGURE 4-18
Oxygen sensor output voltage curve. (Courtesy of Chrysler Motors Corp.)

thimble are plated with platinum electrodes. The inside surface of the thimble forms the negative electrode; the outside is the positive.

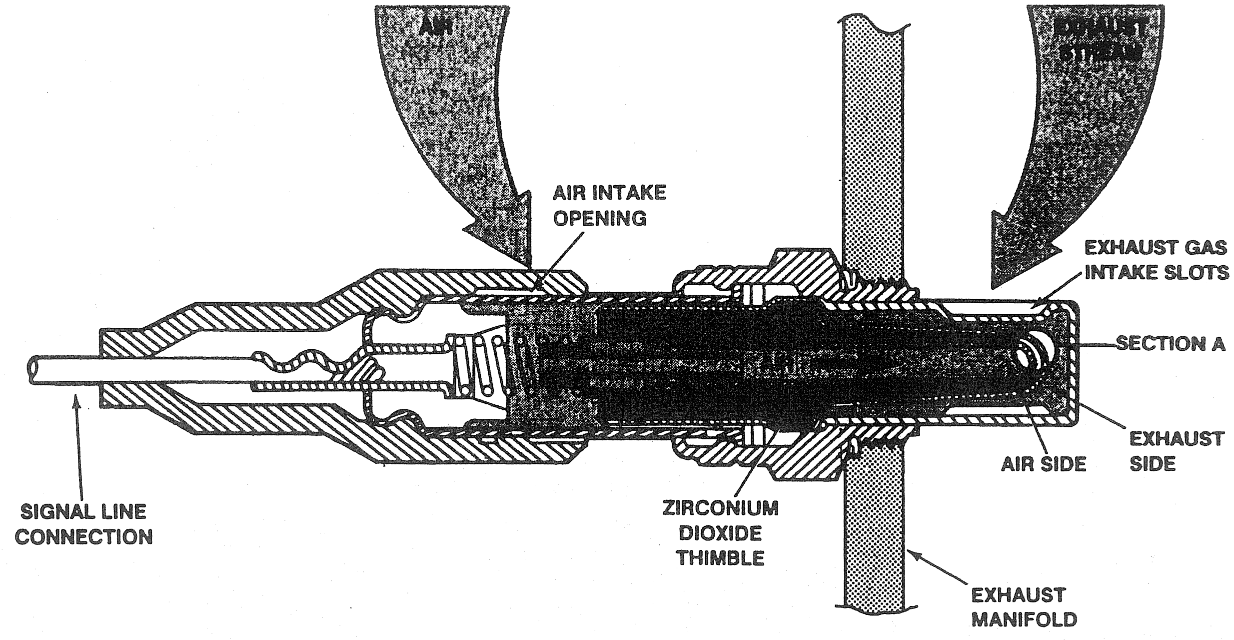
In operation, the zirconium dioxide material attracts negatively charged ions of oxygen. These negative ions collect on both the inside and outside surfaces of the thimble. Since there is more oxygen in air than in the exhaust gas, the air side of the thimble connects more negative ions than the exhaust side does. This difference in the number of negative ions creates an electrical potential (i.e., voltage) between the air and exhaust sides of the thimble.

When there is a low concentration of oxygen on the exhaust side of the thimble (a rich mixture), a high voltage is generated between the two electrodes. On the other hand, a high concentration of oxygen on the exhaust side of the thimble (a lean mixture) produces a low voltage (Fig. 4-20). In either case, the sensor relays the resulting voltage signal to the processor.

Magnetic Pickup Sensors

Magnetic sensors are used to monitor the position and speed of the crankshaft and provide this information by generating a voltage signal to the microcomputer. The microcomputer uses the signal to determine such factors as ignition timing and fuel injection periods. There are two principal types of magnetic sensors, the magnetic pickup and the Hall-effect sensor.

A typical magnetic pickup consists of a wire coil and a permanent magnetic core (Fig. 4-21). The permanent magnet is necessary to create a magnetic field in and around the wire coil.



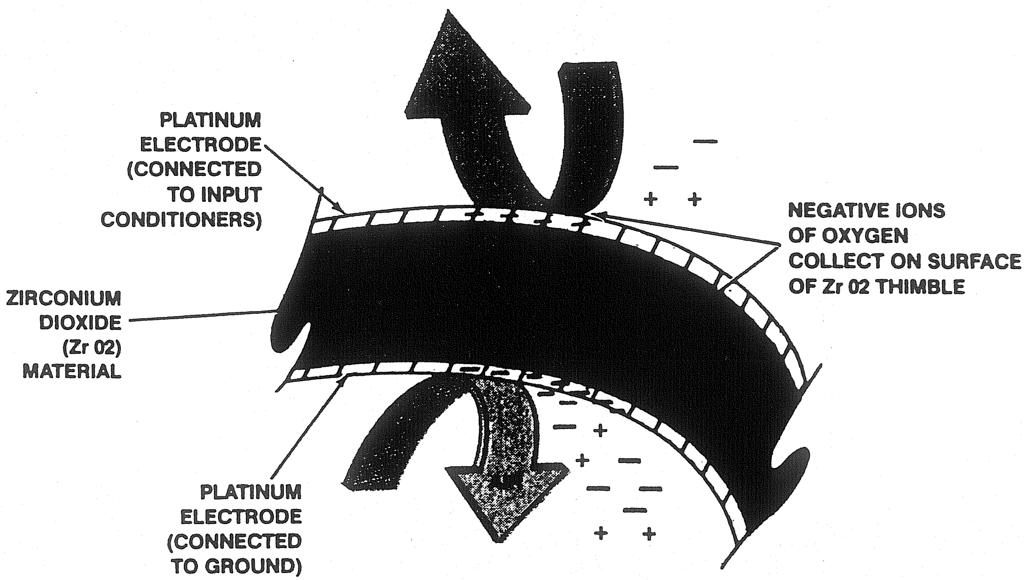


FIGURE 4–19
Design and operation of an oxygen sensor. (Courtesy of Ford Motor Co.)

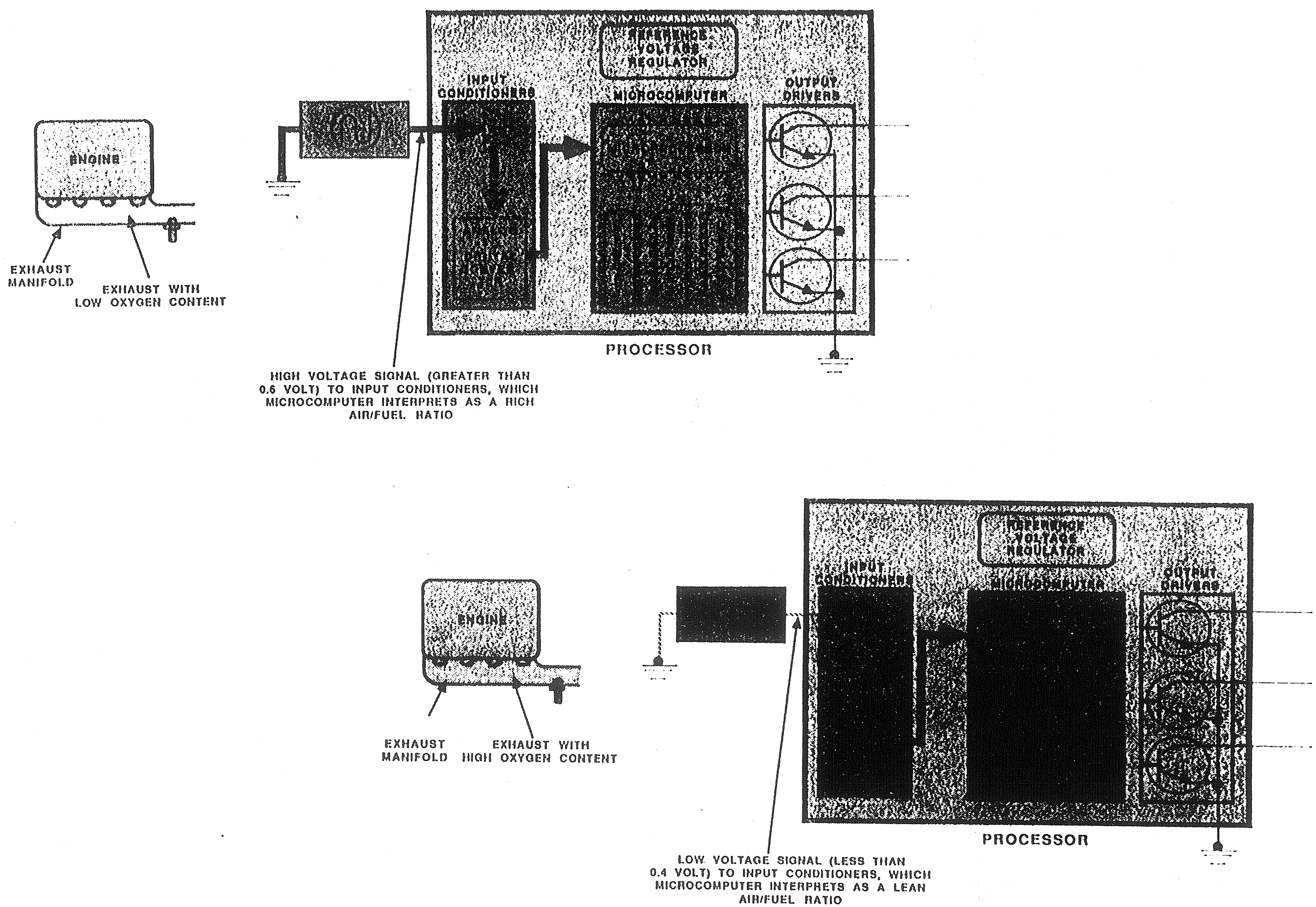


FIGURE 4-20
Sensor input signals during low and high oxygen content in the exhaust gases. (Courtesy of Ford Motor Co.)

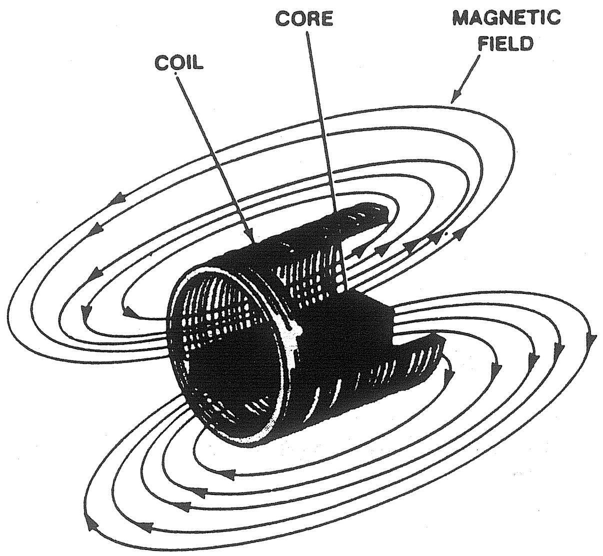


FIGURE 4-21
Typical magnetic pickup design. (Courtesy of Ford Motor Co.)

When a metallic object disturbs the strength of the magnetic field, an electrical voltage is generated in the wire coil. The resulting AC analog voltage signal is then relayed to the microcomputer.

A crankshaft position (CP) sensor is an example of a magnetic pickup (Fig. 4-22). The CP sensor is mounted in a bracket on the engine block. The tip of this sensor contains the magnetic pickup assembly. The metallic object used to disturb the magnetic field is in the form of a pulse ring that is mounted on the crankshaft. Additional information on the CP and distributor pickup type sensors is presented in Chapters 6, 8, and 10, which discuss ignition.

Hall-Effect Sensors

The *Hall-effect sensor* performs the same function as the magnetic pickup mentioned above. However, this sensor provides the signal using a different principle and produces a DC digital signal to the microcomputer. Because it produces a digital signal, which is very accurate, the use of Hall-effect sensors has become very popular with manufacturers.

A Hall-effect sensor can be located within the distributor or be an external device. Figure 4-23 illustrates a Ford profile ignition pickup (PIP) sensor that is of the Hall-effect design. The PIP sensor consists of a rotary vane cup and a Hall-effect switch. The rotary vane cup is positioned at the top of the distributor shaft. In addition, the cup has a set of vanes around its edge, one for each engine cylinder.

The Hall-effect switch is located in the distributor base. The switch contains a permanent magnet on one side, a Hall element (a gallium arsenate crystal) on the other, and two metal plates called magnetic field concentrators. The Hall-effect switch and the rotary cup are positioned so that their vanes

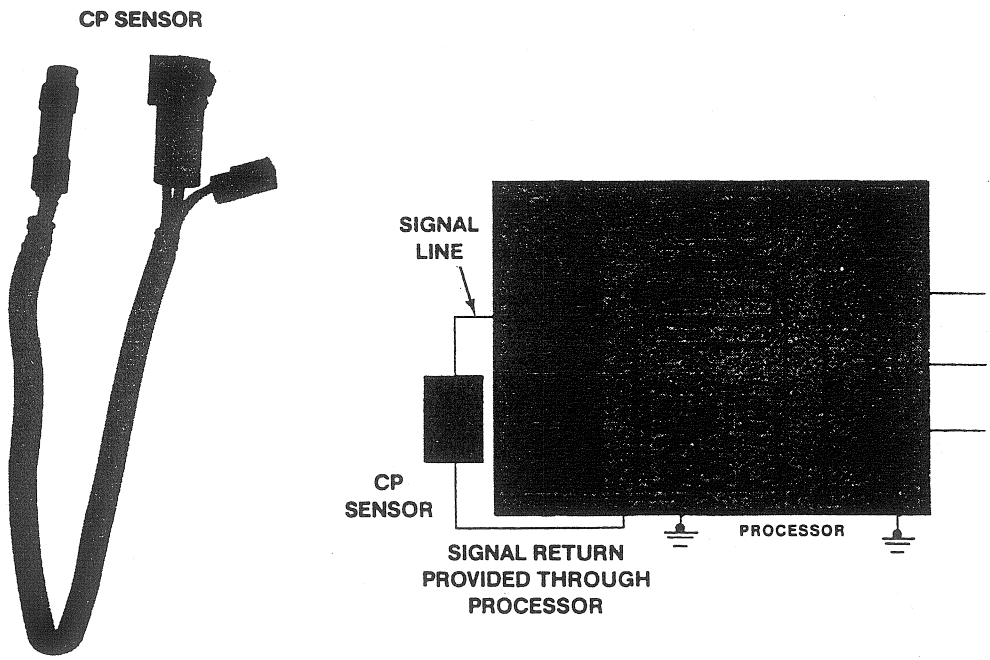


FIGURE 4-22
Schematic of a magnetic pickup circuit. (Courtesy of Ford Motor Co.)

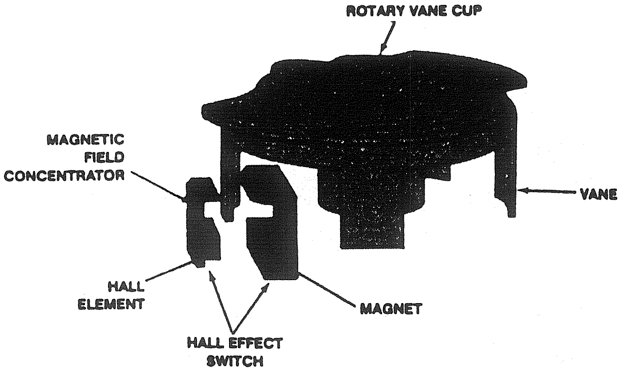


FIGURE 4-23
Typical Hall-effect sensor design. (Courtesy of Ford Motor Co.)

pass through the switch gap as the distributor shaft turns.

The Hall-effect element has three electrical leads (Fig. 4-24). The battery supplies 12 volts to one lead. The second lead is connected to a ground circuit. The third lead supplies the signal to the microcomputer.

The Hall-effect switch uses the effects of magnetism to generate a voltage in its crystal. The main difference between the Hall-effect switch and the magnetic pickup sensor is that the crystal in the Hall-effect switch has a voltage applied to it in a given direction. If the magnetic field passes through the Hall element with voltage applied to it, a signal is generated in the third wire attached to the crystal. This signal is then relayed to the microcomputer. Additional information about the design, operation, and specific applications of Hall-effect sensors can be found in Chapters 6, 8, and 10.

Input Conditioning—Amplification

As mentioned, a microcomputer requires certain types of input voltage signals in order to function. However, as pointed out in this section, input devices produce a wide range of voltage signals. In other words, the signal may be small, large, analog, or digital. Depending on its basic design, most signals must be prepared by special *input conditioning* or *interface circuits* before the microcomputer can use them to process information. The circuits also have a second function. That is, they protect the delicate electronic components in the microprocessor from high voltages that can occur in electrical circuits. There are two principal types of input conditioning processes, (1) amplification and (2) analog-to-digital conversion.

Some sensors like the oxygen sensor and magnetic pickup produce a very weak signal. The oxygen sensor, for instance, produces less than a one-volt signal. Such small signals require amplification, or strengthening, before they can be used by the microcomputer. Figure 4-25 shows the schematic symbol for an *amplifier,* which strengthens a small input signal before it is relayed to the microcomputer.

Analog-to-Digital Conversion

As mentioned earlier, a digital microcomputer must have input signals in DC digital form before it can process information. The simple reason for this is that in these units, the assembly of thousands of tiny switches can have only two states, on or off. That is, the switches are either closed or open. This

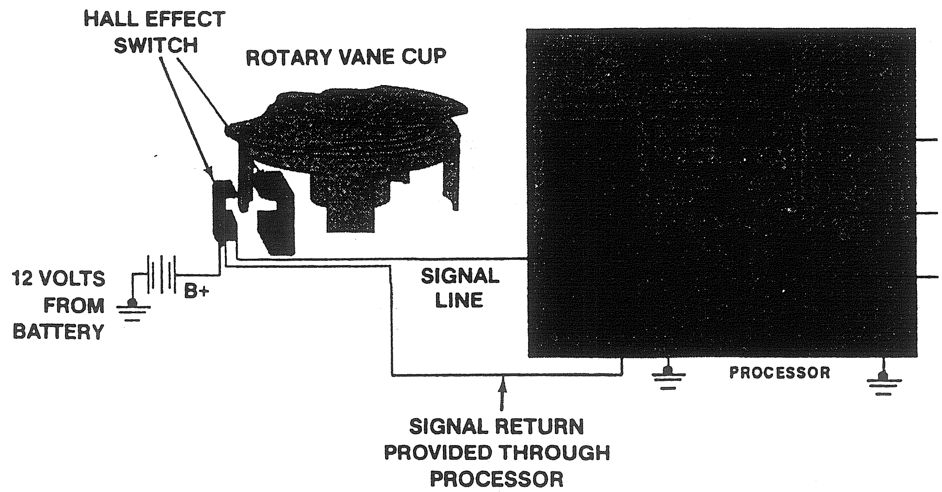


FIGURE 4-24
Hall-effect switch circuit. (Courtesy of Ford Motor Co.)

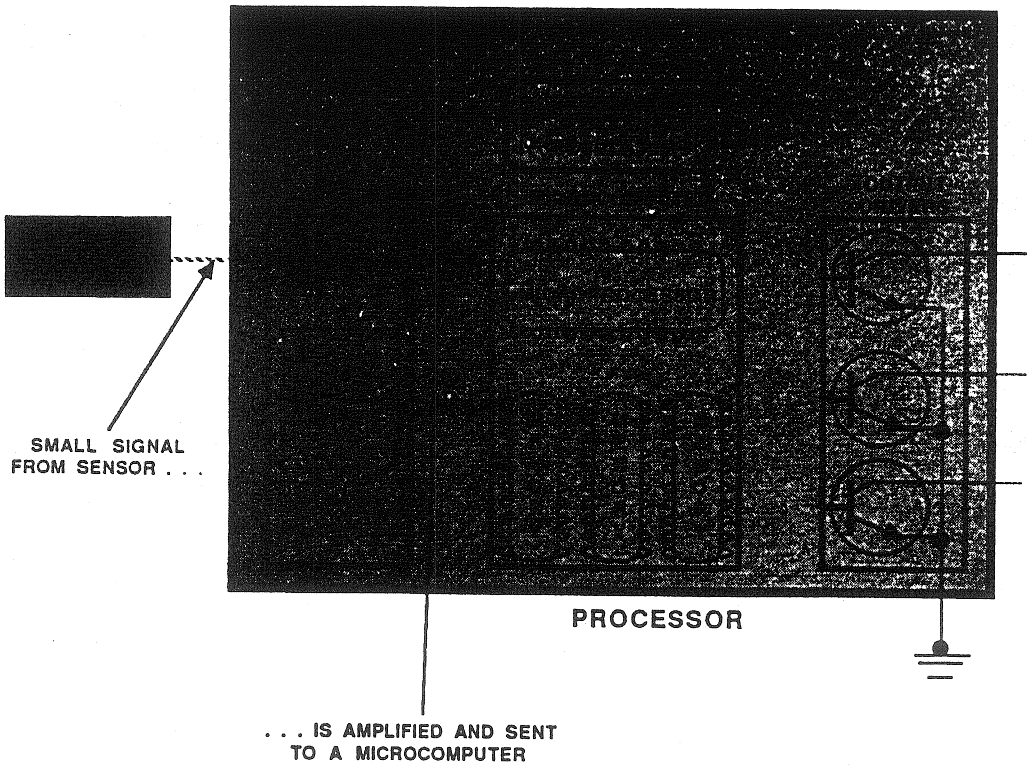


FIGURE 4–25
Typical signal amplifier. (Courtesy of Ford Motor Co.)

requires the input of digital, binary-coded 0 or 1 signals.

If all sensors produced digital signals, the microcomputer could use them to begin its processing function without any intermediate steps. However, many sensors provide a variable analog signal, that cannot be used by a digital microcomputer without converting it. This form of signal conditioning is called *analog-to-digital conversion,* or *A/D conversion.* This task is performed by the analog-to-digital converter (Fig. 4–26).

During the conversion process, voltages from a sensor are classified into different ranges (Fig. 4–27). In the example shown, the three ranges are: 0 to 2 volts, 2 to 4 volts, and 4 to 5 volts. Each voltage range is then assigned a numeric value: 0 to 2 volts = 1, 2 to 4 volts = 2, and 4 to 5 volts = 3.

These numeric values are then assigned a binary code: 1 = 01, 2 = 10, and 3 = 11.

Each analog signal is sampled at regular intervals during the process of conversion. In sampling, the A/D converter takes a picture of the analog signal and determines its voltage at that moment in time. In our example, the voltage is 5 volts.

This voltage is assigned a numeric value of 3. This figure is then translated into a binary code of 11, which, in turn, is relayed to the microcomputer as a digital signal.

In some installations, the microcomputer controls electrical devices that respond to analog signals. In this case, the microprocessor will have a digital-to-analog signal conditioner or interface to change the signals back.

4-4 PROCESSING INFORMATION

Before discussing how the microcomputer processes input signals and makes decisions, let's examine its basic structure and the function of its basic components.

Microcomputer Construction

A microcomputer, or processor, consists of two primary components, the microprocessor and memory (Fig. 4–28). The microprocessor is the part in which all the logical decisions are made. In other words, it is the thinking or calculating portion of the microcomputer.

The microprocessor is the *hardware* package of

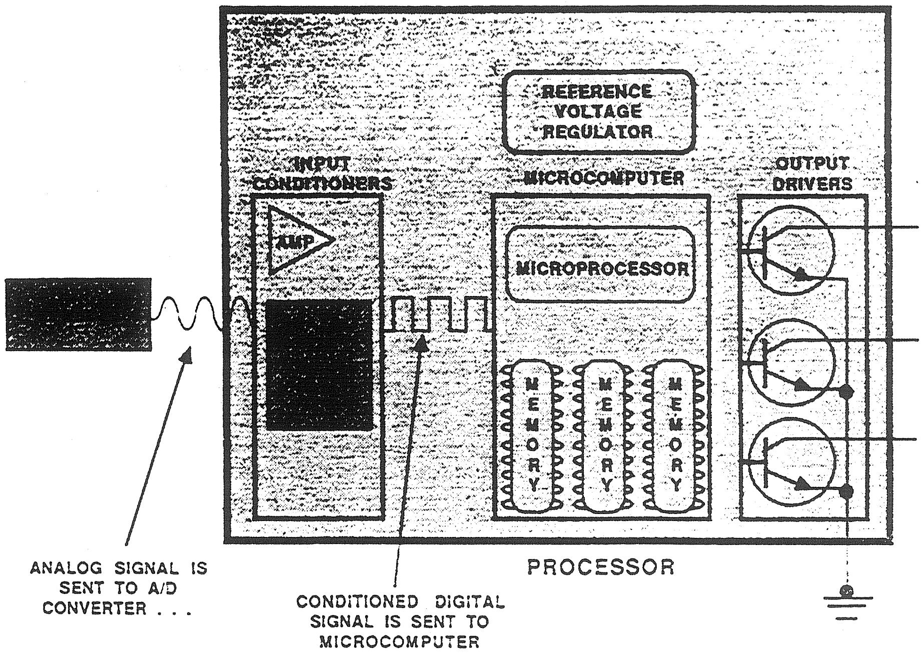


FIGURE 4–26
A/D converter. (Courtesy of Ford Motor Co.)

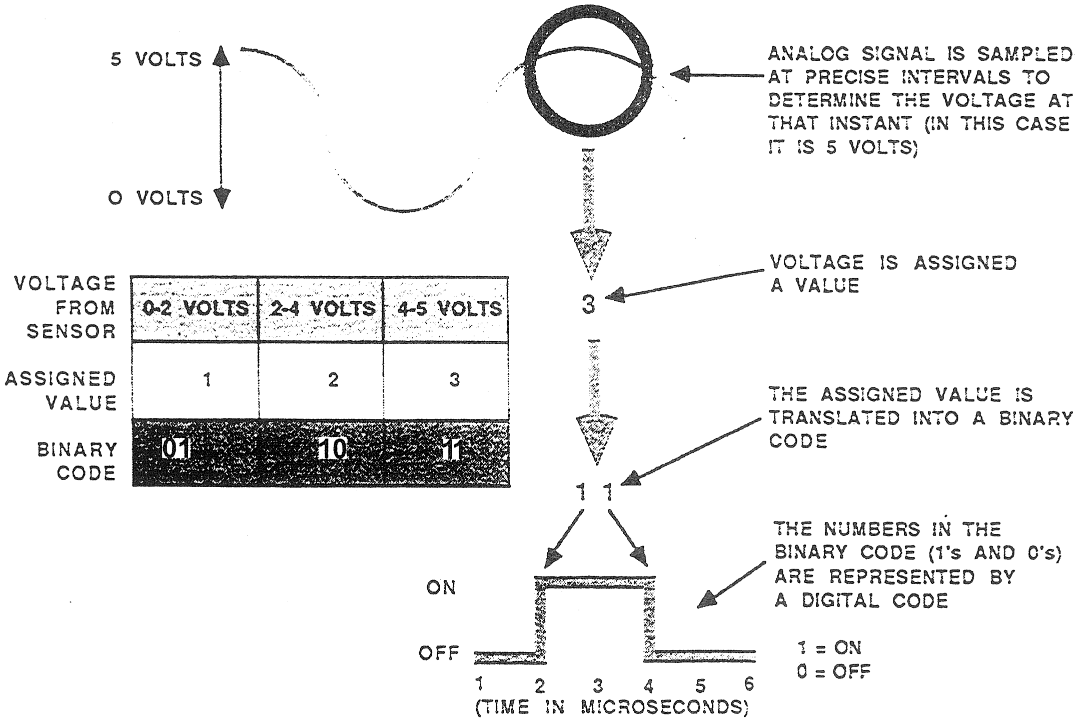


FIGURE 4–27
Analog-to-digital conversion. (Courtesy of Ford Motor Co.)

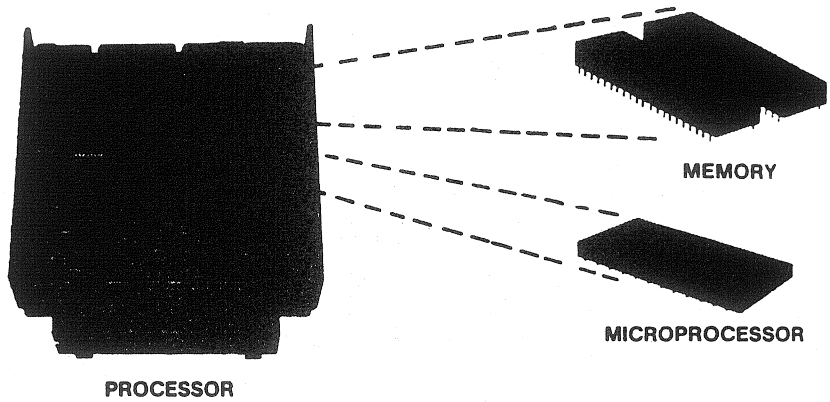


FIGURE 4-28
Processor design. (Courtesy of Ford Motor Co.)

the microcomputer. The unit can only make the decisions or take the actions that are programmed into its circuitry. In other words, the microprocessor can only function according to a built-in program. A *program* is a set of instructions or procedures that the unit follows. The instructions may tell the microprocessor when to retrieve input from a sensor, how to process that information, and when to activate an output device. Consequently, the program guides the microprocessor as it makes decisions.

In order to make accurate decisions, the microprocessor needs as much information as possible. The microprocessor obtains this information from the input sensors or from memory. *Memory* holds the programs and other data, such as vehicle calibrations and information, that the microprocessor refers to in performing calculations. The microprocessor works with memory in two ways. First, the microprocessor can read, or access, information from memory. Second, it can change information in memory by writing new data.

Memory makes up the *software package* of the microcomputer (Fig. 4-29). Changes can be made to the software to alter the microprocessor operation without redesigning it. Just keep in mind, the hardware processes the software. For this reason, manufacturers can use the same microprocessor on a family of vehicles but have different software packages tailored to the particular engine, transmission, vehicle weight, and accessory configuration.

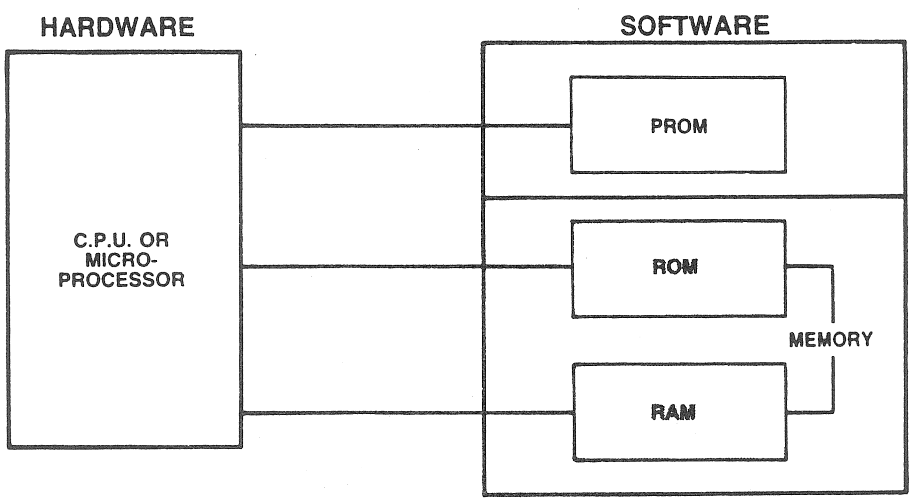


FIGURE 4-29
Hardware and software packages. (Courtesy of Chrysler Motors Corp.)

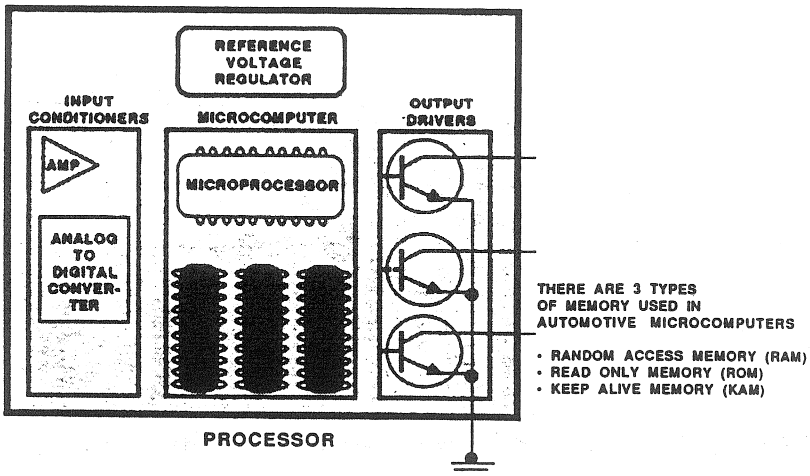


FIGURE 4-30
Processor with three types of memory. (Courtesy of Ford Motor Co.)

Types of Memory—PROM

As shown in Fig. 4-29, this microcomputer uses two types of memory that are stored in the *PROM (programmable read only memory).* They are RAM and ROM. Some types of information in these memory areas are constantly being updated and changed. Other pieces of data are permanent; that is, they must always be available to the microcomputer.

RAM. Information that is to be stored temporarily is directed to a type of memory device known as random access memory (RAM). Random access means that the microprocessor can retrieve information from any RAM location in any order. Moreover, the microprocessor can write, read, and erase information from RAM.

One characteristic of RAM is that if the ignition switch is turned off, the information in RAM is erased. When the vehicle is operated again, information is again written into RAM. RAM is used to store information from sensors, calculation results and other data that are subject to constant change.

ROM. Permanent information is stored in read only memory (ROM). The microprocessor retrieves information from ROM as needed. As its name implies, the microprocessor can only read information from ROM; it cannot erase or write information into ROM.

ROM contains information that is necessary for the vehicle systems to operate. The two types of information stored in ROM are the calibration tables and the look-up tables.

Calibration Tables. The *calibration tables* contain information about a specific vehicle. For example, the tables for one type of engine will contain such data as the number of cylinders, cylinder displacement, and the intake and exhaust valve sizes. The calibration tables for another vehicle engine will contain completely different information. For this reason, the information stored in the calibration tables *matches the microcomputer to a given engine/vehicle configuration.*

Look-Up Tables. The *look-up tables* contain standard information about how a vehicle should perform. These tables are used for *all vehicles.* An example of information stored in the look-up tables is the ideal oxygen content of the exhaust of an engine that is at normal operating temperature and at cruising speed. This datum is compared to the input signal coming from the oxygen sensor to determine if a change in the air/fuel ratio is necessary.

Information is programmed into ROM as the memory device is being constructed. Therefore, this information can never be erased, even if the system is turned off or the battery is disconnected from the processor.

KAM. Some microcomputers have a third type of memory known as keep alive memory (KAM) (Fig. 4-30). KAM has many of the same characteristics as RAM. Information, for example, can be written into KAM and can be read or erased from it. Unlike RAM, data in KAM are not lost when the ignition key is turned off. However, if battery power is disconnected from the processor, information in KAM is erased.

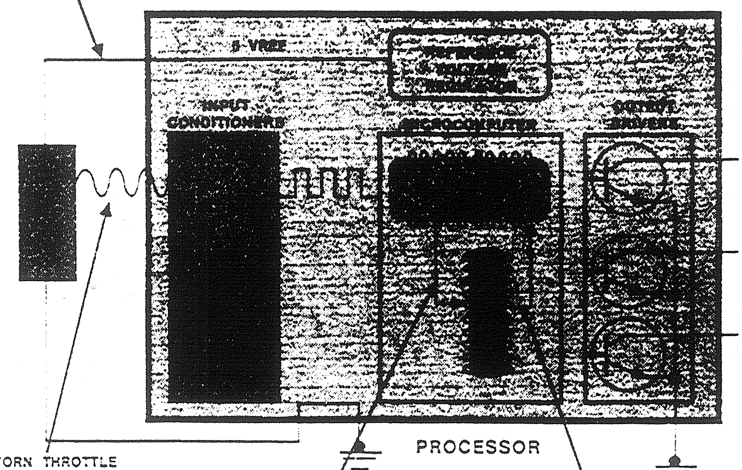


FIGURE 4–31
Example of adaptive strategy. (Courtesy of Ford Motor Co.)

KAM has permitted the development of adaptive strategies used in a number of current electronic engine control systems. Adaptive strategy is the ability for a microcomputer to learn from past experience. Adaptive strategy allows a microcomputer to correct for wear and aging of some parts in a system.

The information that the microcomputer learns during vehicle operation is stored in KAM (Fig. 4–31). KAM retains data on component calibrations so they will not be lost when the engine is turned off.

When the microcomputer executes adaptive strategy, it monitors the input signals from the system components. If the microcomputer detects any signs of age or wear in a calibrated part, it executes the necessary corrections to maintain system performance. If the signal from a sensor should be very erratic, the microcomputer may even ignore the input.

For a microcomputer with the adaptive strategy feature, a short adjustment or learning period will occur (1) on a new vehicle, (2) when the battery has been disconnected during normal use (disconnecting the battery from the processor causes the information in KAM to be lost), and (3) when a component is disconnected or replaced.

If a part is replaced, it is possible for vehicle performance to actually deteriorate because the new component will be treated by the processor as if it were still aged or inoperative. In other words, during the learning period (usually under five miles), some vehicles could exhibit abnormal driveability conditions such as surge, or high or low idle speeds.

Information Storage and Retrieval

Each type of microcomputer memory consists of a number of data locations. Each location contains one piece of information. Moreover, each memory location is assigned a number called an *address* (Fig. 4–32). Addresses are in binary code and are numbered sequentially starting with zero. The microcomputer uses the addresses to retrieve information and to write data into memory.

During processing, the sensors relay information to the microprocessor, but it may not be possible for the unit to process all this data immediately. In other words, some information has to be stored. To store the data, the microprocessor writes it into memory by specifying an address and then sending the data to that location.

The microprocessor can retrieve information stored in memory by reading the data. The microprocessor does this by specifying the memory loca-

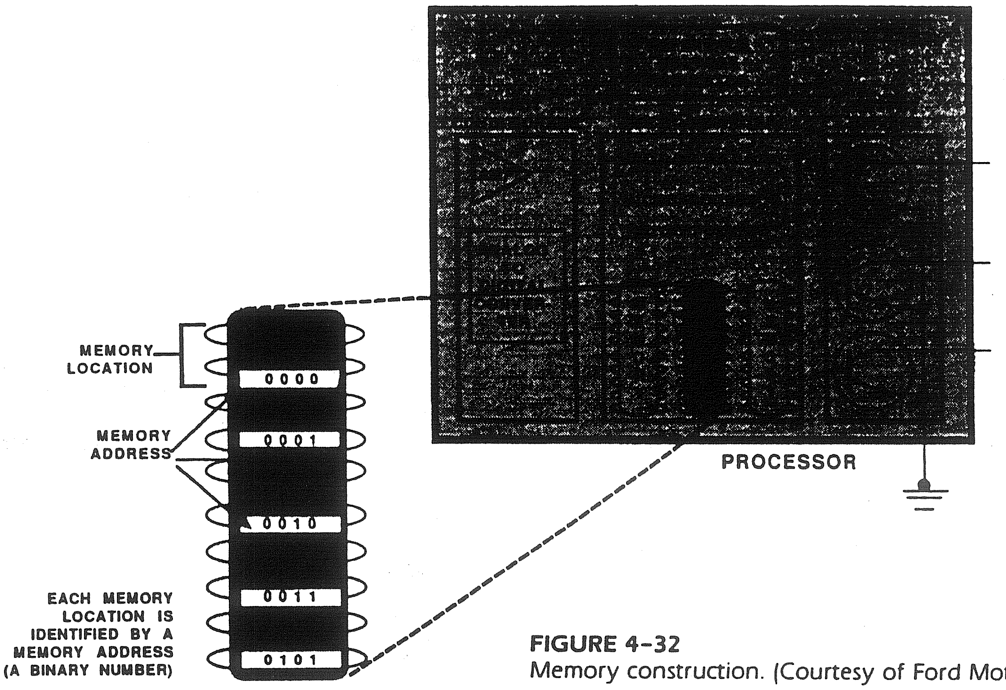


FIGURE 4-32
Memory construction. (Courtesy of Ford Motor Co.)

tion (address) and requesting that the information be sent.

When that particular memory location sees that it is being addressed, it sends a copy of the stored information to the microprocessor. The original data stays in the memory location and can be accessed later if necessary.

Microcomputer Clocks

Microcomputers contain some form of *clock generator* that provides constant steady pulses, each the length of one bit (Fig. 4-33). The microprocessor and the memories watch these clock pulses while they are reading or sending data, which lets the components know how long each voltage pulse (representing a bit) is supposed to last. This is how the microcomputer components can distinguish between a 01 and a 0011 binary code.

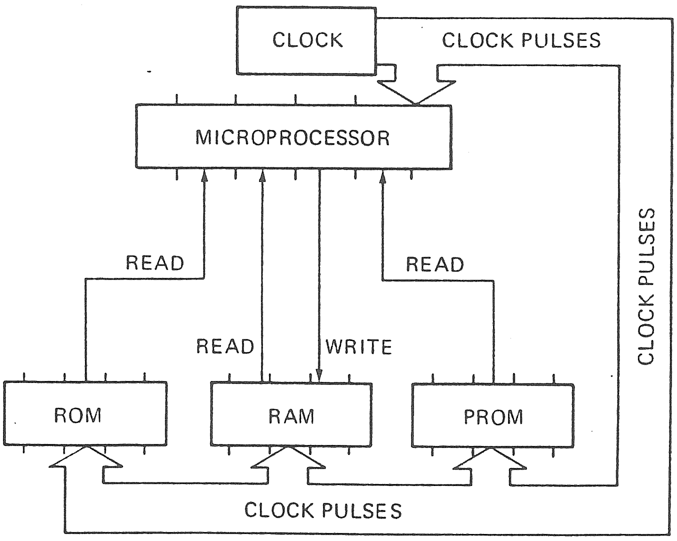


FIGURE 4-33
Microcomputer clock.

Data Links

Microcomputers send and receive digital signals through what are called *data links.* Some data links transmit data only in one direction, that is, from one device to another (Fig. 4-34). Other types of data links can transmit both ways, from one device to another and back again. In some cases, the microcomputer may send signals to several devices over one data link. In this situation, the microcomputer is programmed to recognize each bit by its place in the data stream. This is how the microcomputer knows where to send or store a bit of information.

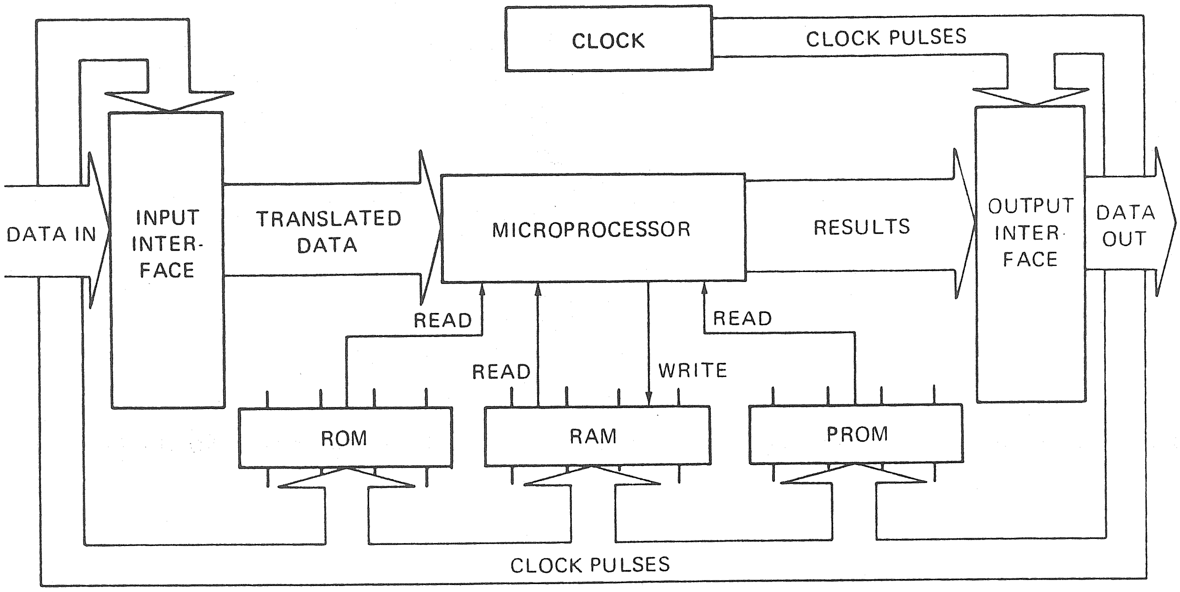


FIGURE 4–34
Microcomputer data links.

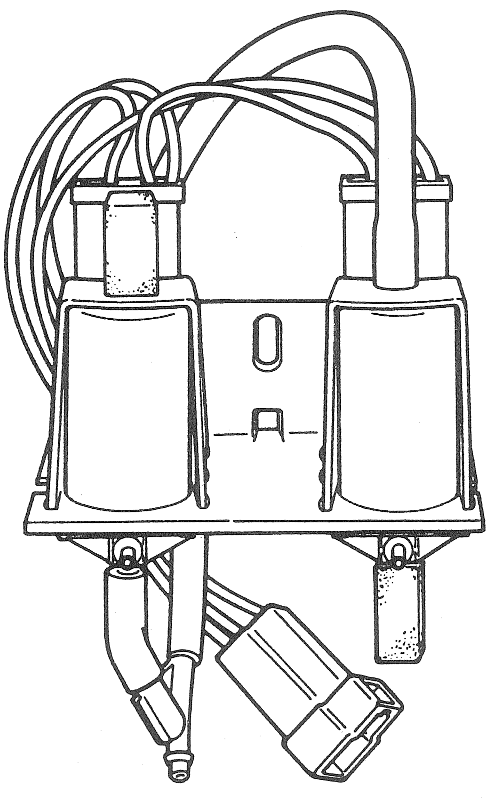


FIGURE 4–35
Typical output actuators in the form of solenoid-operated vacuum valves. (Courtesy of Chrysler Motors Corp.)

4-5 MICROCOMPUTER OUTPUT DEVICES

Thus far, this chapter has discussed how a microcomputer receives data about vehicle operating conditions from a variety of sensors. In addition, the design and operation of some of these sensors and how their analog signals are converted to digital has been explained.

It is now time to consider output, the third stage of microcomputer operation. Operational control of output devices involves either some form of actuator (Fig. 4–35) or an information display.

The microcomputer receives and processes input signals as programmed. The unit must then make a decision about engine operating conditions and act. To put the decision into action, the microprocessor issues commands in the form of voltage signals (usually digital), which, in turn, energize the output device.

Output Drivers

Before looking at different types of actuators, let's see just how a microprocessor energizes them. After a decision is made, the microprocessor relays a digital voltage signal to an output driver, which, in turn, completes an electrical ground circuit to an actuator (Fig. 4–36). Therefore, the output drivers do not supply voltage to the actuators. Their voltage is supplied by the battery.

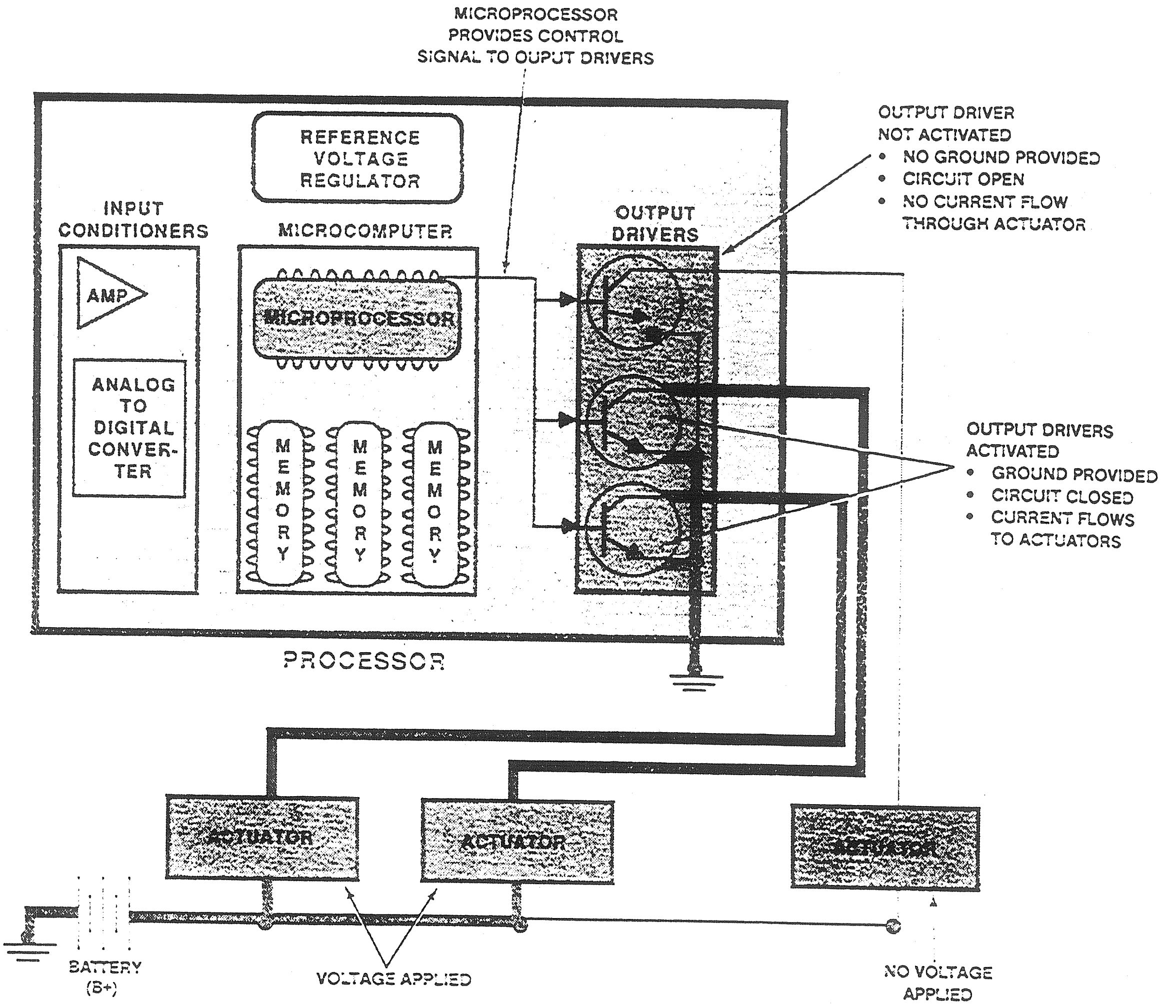


FIGURE 4-36
Output drivers energize the actuators. (Courtesy of Ford Motor Co.)

Output drivers are electronic switches (transistors); the ones shown in Fig. 4-36 are the NPN type. The microprocessor turns the output drivers on and off by directing a voltage signal to its base or gate circuit.

With a voltage signal on the gate circuit, the driver turns on. This action completes the actuator ground circuit, and current flows through it. If the microprocessor turns off the gate signal, the actuator ground circuit is broken, and no current flows. Thus, by using the output drivers to turn the actuators on and off, the microprocessor provides output control.

Actuators

An *actuator* is a device that converts electrical current into some form of mechanical motion using electromagnetism. There are three principal types of actuators in use: the solenoid, relay, and motor. Using these three devices, the microcomputer can control just about any portion of an engine control system.

Solenoids. As explained in Chapter 2, a solenoid uses electrical current through a coil of wire to create an electromagnetic field. This field, in turn, pulls a metal plunger into an air core inside the coil. A spring is used to push the plunger back out of the core when no current is flowing through the coil.

There are many types of solenoids used in electronic engine control systems. These include EGR control and vent solenoids, air diverter and bypass solenoids, canister purge and carburetor vent solenoids, and carburetor mixture-control solenoids.

Figure 4-37 illustrates the operation of a typical solenoid-operated vacuum valve. When the mi-

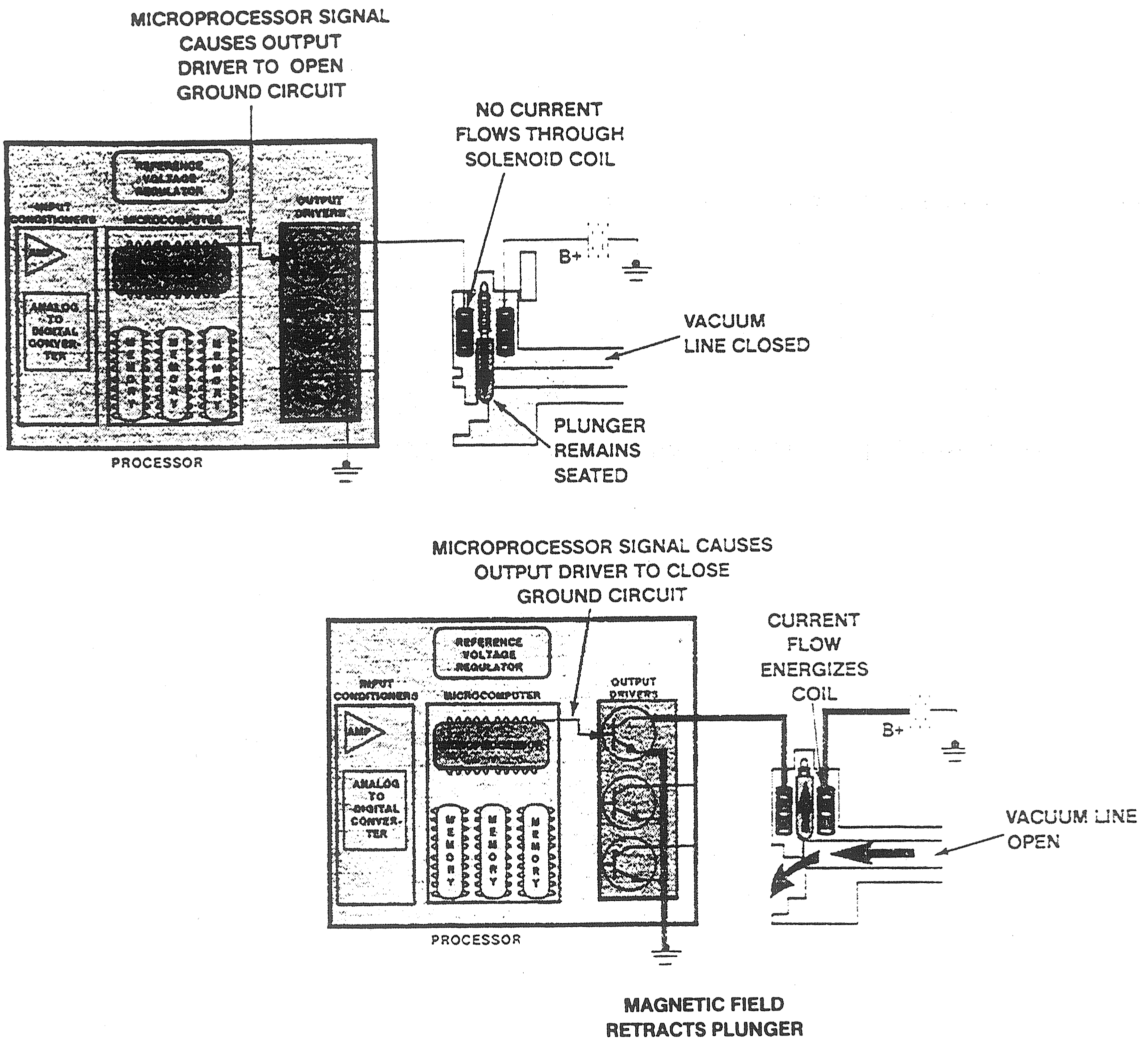


FIGURE 4–37
Operation of a solenoid-type actuator. (Courtesy of Ford Motor Co.)

croprocessor does not provide a positive voltage signal to the output driver, it opens, as shown. As a result, no current flows through the solenoid coil. There is no magnetic field created, and the spring holds the plunger valve against its seat. This effectively blocks the vacuum signal.

Whenever the microprocessor directs a positive voltage signal to the gate of the output driver, it closes. Electric current now flows through the solenoid coil windings and to ground via the output driver. This action creates a magnetic field that attracts the plunger into the air core. With the plunger valve off its seat, the vacuum passage is now open.

Relays. As mentioned also in Chapter 2, a relay is an electrical device that uses a small current to control the flow of a second, larger current. To perform this task, the relay has a wire coil, relay switch, and two circuits, a control and power. Current through the control circuit is used to govern the electron flow through the power circuit. This circuit then delivers current to another component. In Fig. 4–38, this part is a cooling fan motor.

In operation, the microprocessor either directs or stops a digital signal to the gate of an output driver, which controls the ground circuit for the relay. Without a positive signal on the gate, the output driver remains open. As a result, current cannot pass through the relay coil and to ground via the driver. With the relay control circuit open, so is the power circuit. Therefore, the cooling fan is not energized and will not run.

When the microprocessor provides a positive signal to the gate, the driver turns on and completes

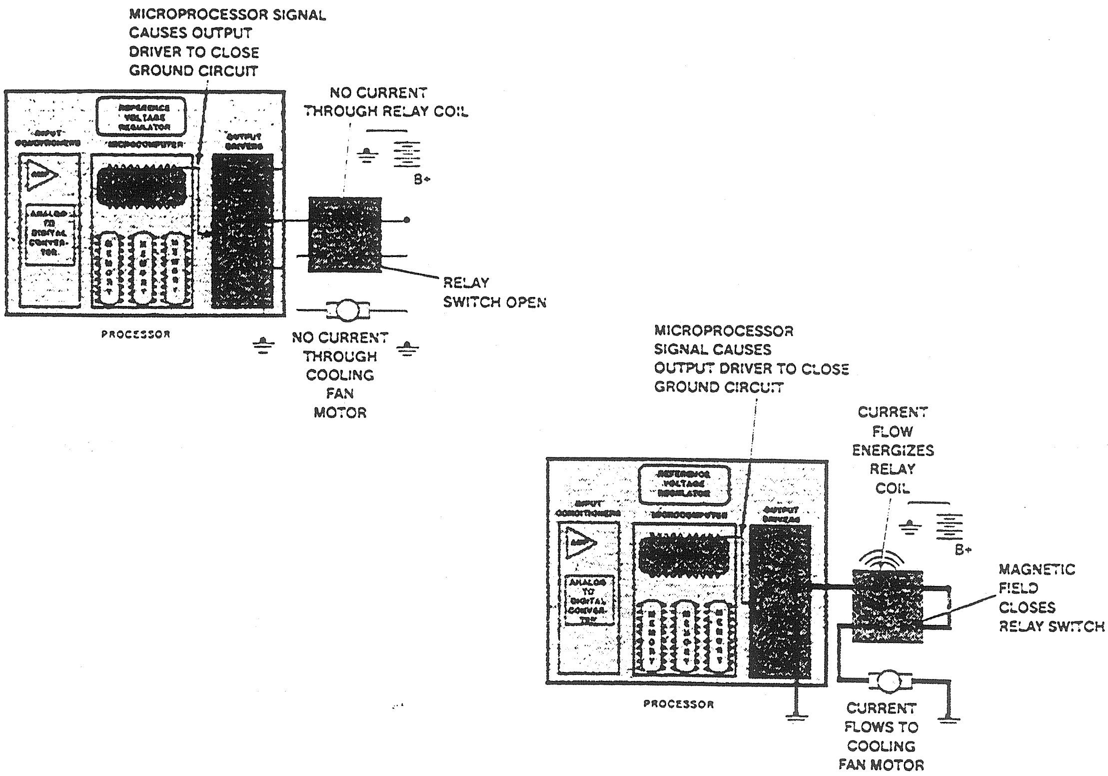


FIGURE 4-38
Design and operation of a relay-type actuator. (Courtesy of Ford Motor Co.)

the ground for the relay control circuit. With current now flowing through the coil, it creates a magnetic field that causes the relay switch to close. Current now can flow through the power circuit to the cooling fan, and it begins to operate.

Motors. Most electronic engine control systems incorporate an electric motor to control idle speed. The basic function of the *idle speed control* (ISC) motor is to regulate engine speed during all periods of closed throttle operation (Fig. 4-39). The motor performs this function during cold and hot operating conditions and compensates for additional accessory loads placed on the engine that can affect idle speeds. In addition, the ISC will adjust the idle speed whenever abnormal engine-operating temperatures are encountered.

The ISC is a reversible motor that adjusts idle speed by changing the throttle opening. It does this by acting as a moveable idle stop. The microprocessor, via the appropriate driver, energizes the ISC motor to either raise or lower engine speed, thus maintaining the correct idle required for a particular operating condition.

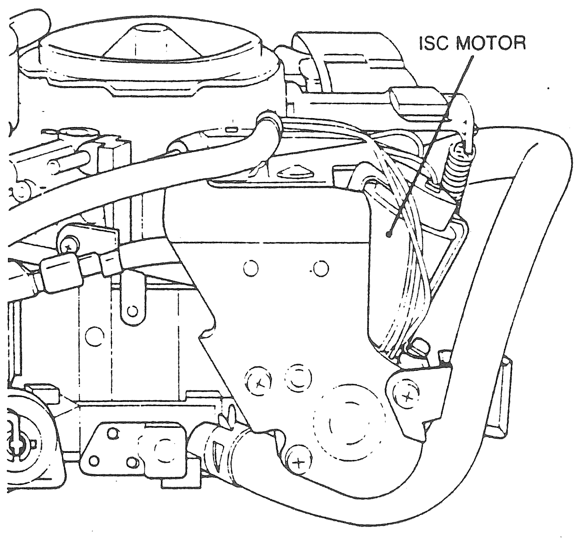


FIGURE 4-39
Typical idle speed control motor. (Courtesy of Chrysler Motors Corp.)

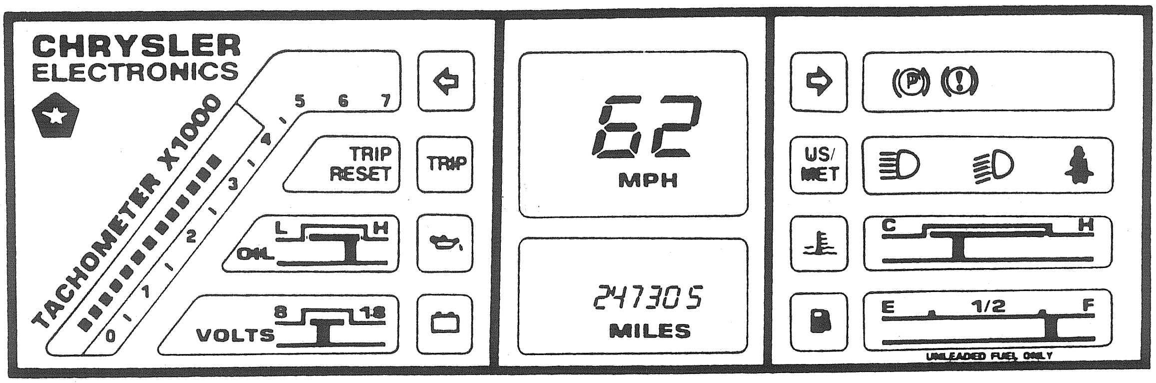


FIGURE 4-40
Typical output display. (Courtesy of Chrysler Motors Corp.)

Displays

The microprocessor controls a display by sending a digital signal to it. A *display* is a solid state device that contains the circuitry to decode digital signals. The decoded information appears on the display (Fig. 4-40).

The digital signal from the microprocessor carries data to the display in the form of a binary code. Figure 4-41 shows how the binary digital signals transport information. In the example, the numbers to be displayed are 1, 2, and 3. The microprocessor represents these numbers by relaying to the display the specific binary code, as shown. These signals are then decoded and displayed. Note in Fig. 4-41 that the output drivers have no function whenever the microcomputer output is used for display.

4-6 MICROCOMPUTER OPEN AND CLOSED LOOP CONTROL

The microcomputer used in engine control systems performs its functions by following three stages of operation. First, it receives input. Second, it processes that input, and third, it provides output.

Open Loop Control

The microcomputer three-stage operating sequence is referred to as *open loop control* (Fig. 4-42). In open loop control, the microcomputer has no means of directly measuring the results of its output. In other words, it has no way of determining how effective the output has been in changing system performance.

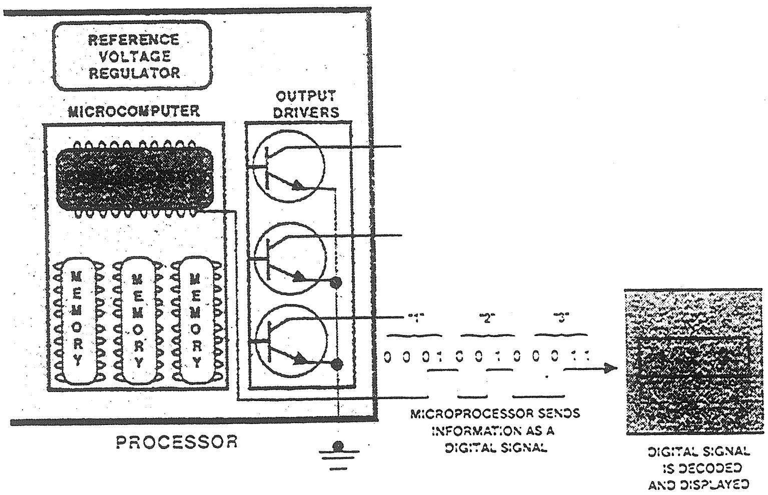


FIGURE 4-41
Data sent to a display as a binary code. (Courtesy of Ford Motor Co.)

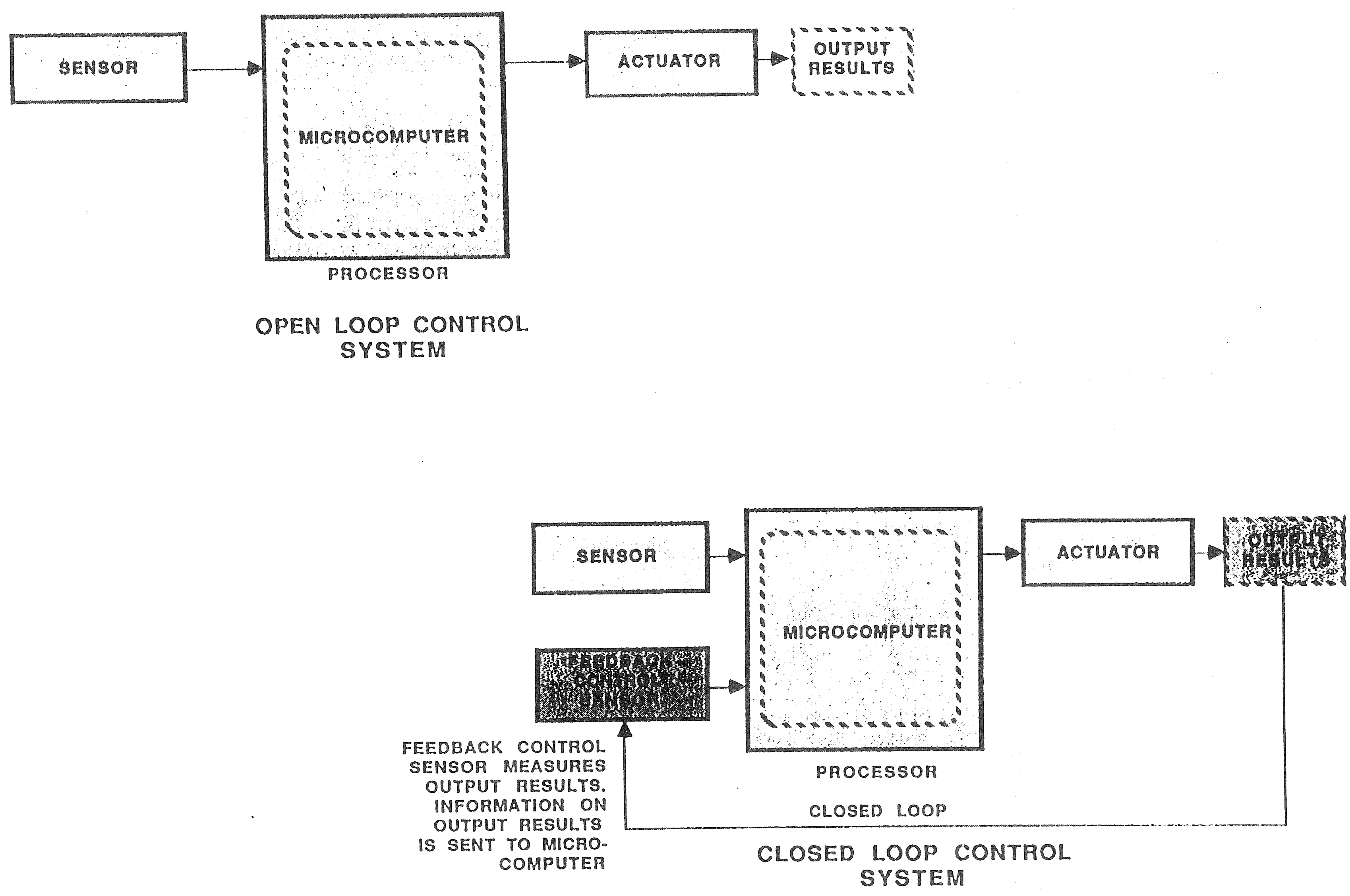


FIGURE 4–42
Open and closed loop microcomputer systems. (Courtesy of Ford Motor Co.)

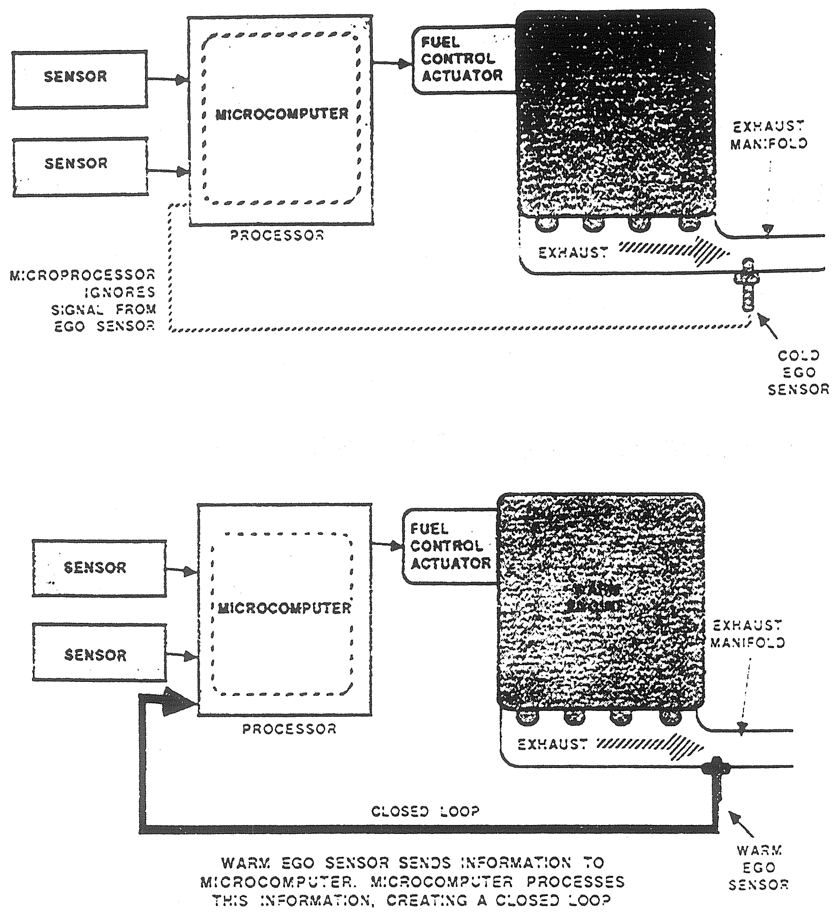


FIGURE 4-43
Open and closed loop system operation. (Courtesy of Ford Motor Co.)

Closed Loop Control

Current engine control microcomputers have a fourth stage of operation called *feedback*. When a microcomputer uses feedback, it is said to be operating in closed loop. In this situation, a feedback control sensor is used to measure the results of the microcomputer output to determine how effective it has been. In this way, a system can be controlled very closely. By adding the feedback control sensor to the open loop system, it becomes closed loop.

The oxygen sensor is a feedback control sensor. It measures the amount of oxygen present within the exhaust gas and relays this information to the microcomputer. With this informaton, the microprocessor can signal a mixture control solenoid or the injectors to adjust the air/fuel ratio to achieve the proper level of oxygen.

When an engine has just started and is still cold, the oxygen sensor signal is not usable until the exhaust temperature reaches about 570°F (300°C). Until then, the microcomputer ignores the signal from the oxygen sensor, and the system operates in open loop (Fig. 4-43).

When other conditions are met and the oxygen sensor is at operating temperature, it signals the microcomputer with air/fuel mixture information. The microcomputer processes this data and makes changes in the mixture as necessary. Therefore, when the microcomputer is processing and acting on information from the oxygen sensor, the system is operating in closed loop.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. What are the four stages of operation a microcomputer follows during closed loop [4-6]?
2. What is a microcomputer [4-1]?
3. Explain how an output driver energizes an actuator [4-5].
4. Explain the difference between analog and digital signals [4-2].
5. What is a microcomputer program [4-4]?
6. Explain what reference voltage is and where it comes from [4-3].

REVIEW

1. If the oxygen sensor is inoperative, the microcomputer cannot provide what type of operation [4-6]?
   a. open loop
   b. closed loop
   c. start-up mode
   d. acceleration mode
2. What is the name given the box that contains the microcomputer [4-1]?
   a. microprocessor
   b. processor
   c. computer
   d. memory
3. What is the most common type of output actuator design [4-5]?
   a. motor
   b. relay
   c. solenoid
   d. display
4. A microcomputer performs work by controlling the operation of what device(s) [4-1]?
   a. solenoid
   b. relay
   c. both a and b
   d. neither a nor b
5. If a microcomputer can learn from past experience, it has what is known as [4-4]
   a. adaptive strategy.
   b. interfacing logic.
   c. limp-in strategy.
   d. learning strategy.
6. How long does it take a microcomputer to act on input information [4-1]?
   a. ½ second
   b. ⅕ second
   c. 1/10 second
   d. 1/15 second
7. Information about the engine in a given vehicle is stored in which memory [4-4]?
   a. RAM
   b. ROM
   c. RIM
   d. EOM
8. A distributor magnetic pickup coil produces what type of signal [4-2]?
   a. AC digital
   b. DC digital
   c. DC analog
   d. none of these
9. What is considered to be microcomputer software [4-4]?
   a. its memory
   b. its microprocessor
   c. its sensors
   d. its output actuators
10. What is the term used to describe the assigning of a numeric value to a voltage signal [4-2]?
    a. a bit
    b. binary code
    c. a bite
    d. none of these
11. That sensor that relays information to the microprocessor concerning crankshaft position and speed is the [4-3]
    a. magnetic pickup coil.
    b. Hall-effect switch.
    c. PIP sensor.
    d. all of these.

12. A Hall-effect switch produces what type of signal [4-2]?
    a. AC analog
    b. DC analog
    c. AC digital
    d. DC digital
13. Which device is mainly responsible for determining an engine's air/fuel ratio [4-3]?
    a. oxygen sensor
    b. detonation sensor
    c. park/neutral switch
    d. clutch switch
14. What is the device that converts mechanical motion into an electrical signal [4-3]?
    a. thermistor
    b. potentiometer
    c. switch
    d. oxygen sensor
15. What effect does temperature have on a thermistor's resistance [4-3]?
    a. Its resistance goes down as its temperature increases.
    b. Its resistance goes up as its temperature decreases.
    c. both a and b
    d. neither a nor b

Chapter 5

TEST EQUIPMENT AND PROCEDURES

OBJECTIVES

After reading and studying this chapter, you will be able to

- describe the function, design, and use of analog and digital voltmeters.
- explain the function, design features, and use of analog and digital ammeters.
- describe the function, design, and use of analog and digital ohmmeters.
- explain the function and how to use test lights and jumper leads.
- describe the purpose of a compression tester, vacuum gauge, vacuum pump, tach/dwell meter, timing light, oscilloscope, and exhaust gas analyzers.
- explain the function of the ignition module tester, STAR tester, breakout box, and aftermarket microcomputer system testers.
- describe the information found on or in emission decals, wiring diagrams, vacuum diagrams, diagnostic charts, and service manuals.
- explain the safety rules that pertain to general automotive maintenance and testing.

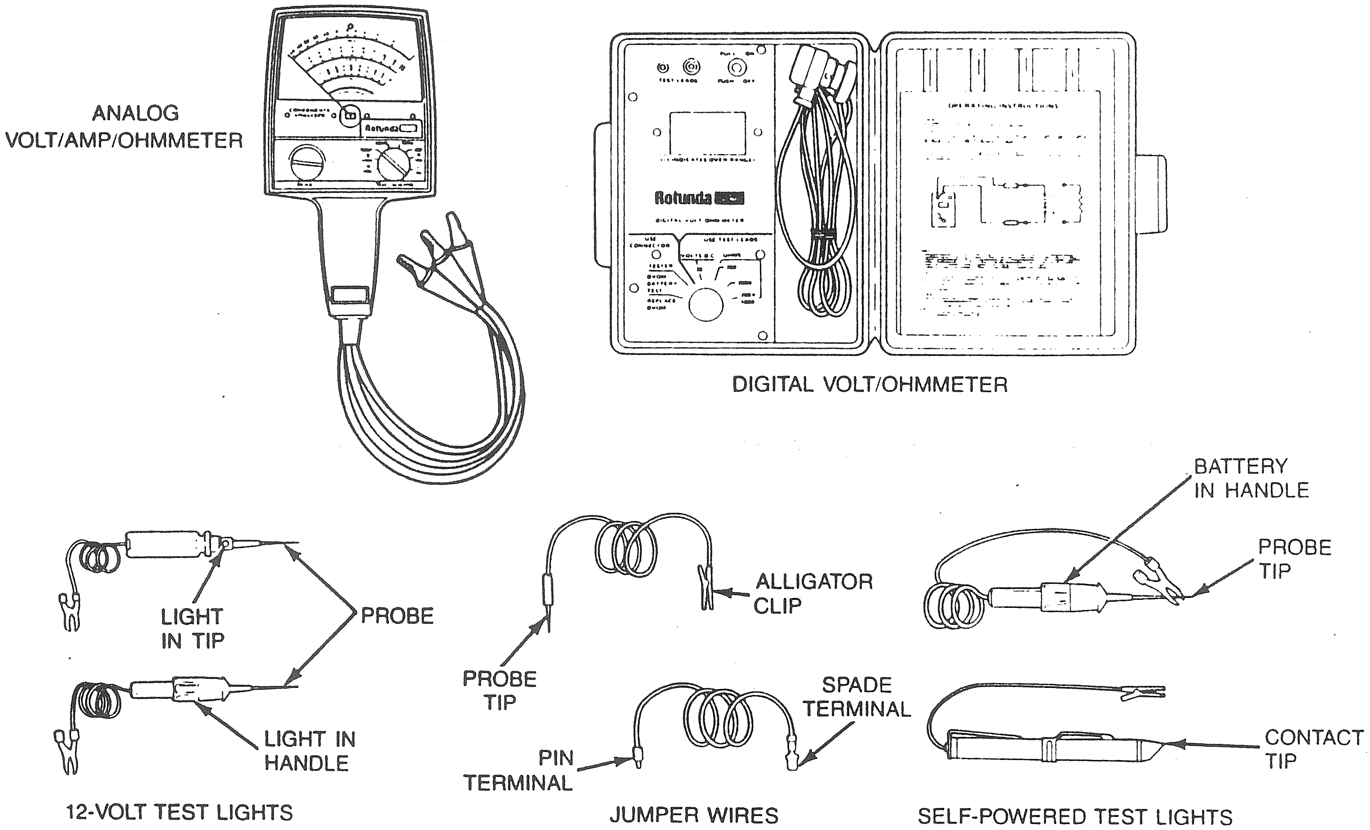


FIGURE 5-1
Typical electrical test equipment. (Courtesy of Ford Motor Co.)

The contemporary automobile has one or a number of microcomputers like those described in the last chapter. These microcomputers consist of electronic components and thus have no moving parts. Theoretically, a microcomputer should last the life of the vehicle, provided nothing external happens to damage its circuits, processor, or memory chips.

While it is true that the controls of a microcomputer-based engine should last longer than similar mechanical types, the microcomputer is extremely sensitive to electrical voltages and cannot tolerate careless or haphazard testing or service procedures. An inexperienced person can literally do major electronic circuit damage looking for a minor problem by either using the wrong type of equipment or connecting up test leads incorrectly.

Therefore, to safely troubleshoot these microcomputer systems requires the technician to be very familiar with the purpose and operation of the testing equipment available (Fig. 5-1). Through the proper use of these tools and information found on electrical diagrams, vacuum schematics, and diagnosis guides found in the various service manuals, the technician can develop the proper approach for identifying a problem and isolating the cause of a malfunction.

5-1 ELECTRICAL TEST INSTRUMENTS

Many of the testers used to measure voltage, current flow, and resistance are sold in a variety of models, and any working model will be adequate for making simple tests. However, when the value of the reading obtained is critical to the diagnostic procedure, accuracy becomes very important. Consequently, make sure the meter used has sufficient quality and accuracy to make the measurement required.

Types of Basic Meters

For automotive electrical system testing, there are two basic types of meters in use, the digital readout and the analog (Fig. 5-2). The *digital readout meter* uses solid state circuitry (a small microcomputer) that converts a measurement taken to a numerical value. In other words, the output of the meter circuitry is in the form of numbers in digital form displayed on a screen. This instrument is the most accurate of the two types.

Features of a typical digital meter include automatic range adjustment, automatic polarity adjust-

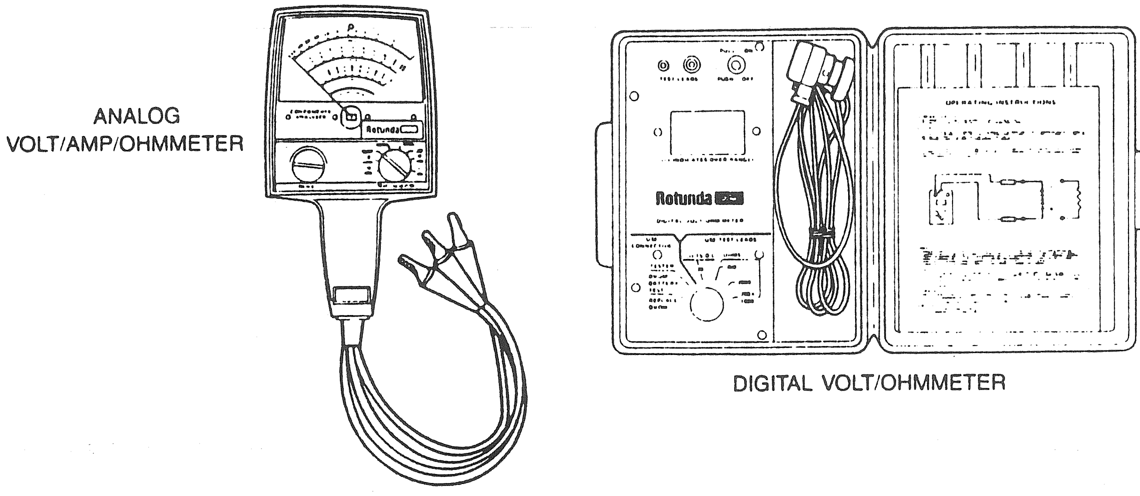


FIGURE 5-2
Digital and analog meters. (Courtesy of Ford Motor Co.)

ment, and accuracy to several decimal points. This last feature is very important when testing computerized system components because some measurements have such a low value that they just cannot be obtained accurately by reading the needle position on a scale.

The *analog meter* shows the actual measurement using a needle that moves across a scale. In the case of an analog voltmeter, the movement of the needle on the scale is in proportion to the actual voltage measurement being taken. If the meter is of the permanent magnet type, it is very durable and accurate enough for most general automotive electrical testing. *However, it should not be used to test components of computerized engine control systems.*

Many meters are multipurpose. For instance, the digital meter illustrated in Fig. 5-2 can measure both voltage and resistance. The analog meter is able to measure voltage, amperage, and resistance.

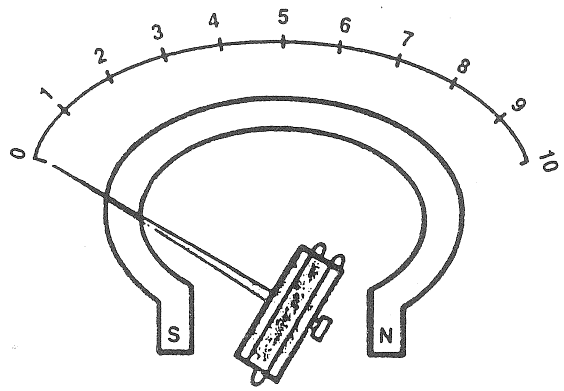


FIGURE 5-3
D'Arsonval movement. (Courtesy of Ford Motor Co.)

Basic Analog Meter Design

All analog meters use the same type of mechanism to indicate the value of voltage, amperage, or resistance. This mechanism is called a *D'Arsonval*, or *moving coil movement*, which uses a magnetic field to force a coil to rotate inside the meter (Fig. 5-3). The movement consists of a permanent magnet, moveable coil, and needle. The coil is made of several turns of wire carefully insulated and wound on a rectangular aluminum frame. The aluminum is nonmagnetic and permits the fast collapse of the magnetic field when the coil is de-energized.

The coil attaches to an indicator needle and pivots on jeweled bearings. Two hairsprings hold the coil in its zero position and also carry the current flow to the coil. Meter calibration is usually accomplished by increasing or decreasing tension on the needle through these springs.

At rest, with no current flowing through the windings of the coil, the needle is pushed to zero by spring force. When a current is applied, the coil becomes an electromagnet, operating within a second magnetic field produced by the permanent magnet.

Figure 5-4 illustrates what occurs when current passes through the moveable coil. With current flowing, the coil becomes an electromagnet with the polarity shown. Since like magnetic poles repel, the coil turns the pointer across the scale in proportion to the current flow through it.

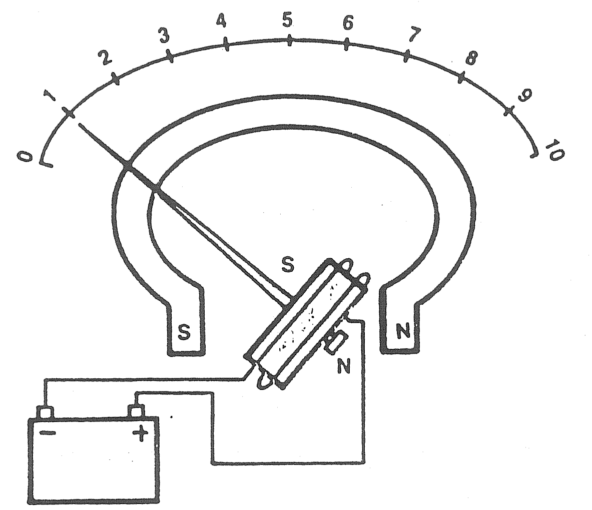


FIGURE 5-4
Current flow deflects needle. (Courtesy of Ford Motor Co.)

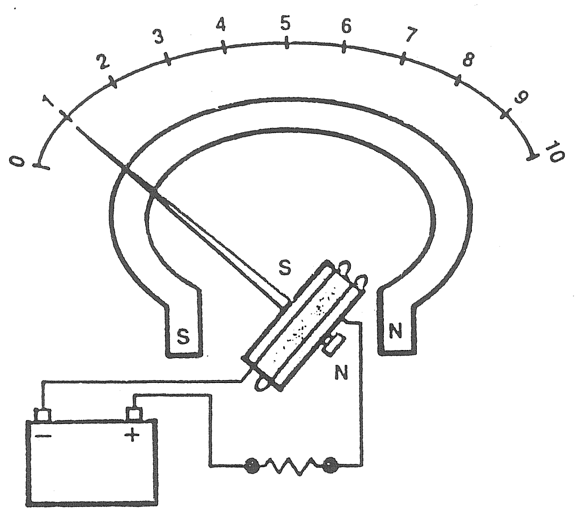


FIGURE 5-5
Basic analog voltmeter design. (Courtesy of Ford Motor Co.)

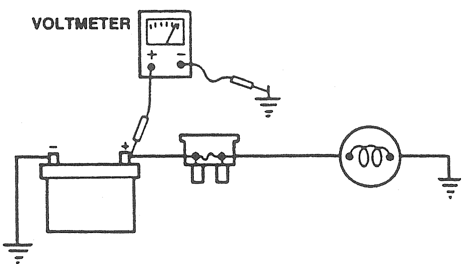


FIGURE 5-6
Voltmeter connected in parallel. (Courtesy of Chrysler Motors Corp.)

5-2 VOLTMETERS

A *voltmeter* is a device used to measure electromotive force (EMF), or voltage, in an electrical circuit. Voltmeters are used to measure such things as the EMF available at a circuit's voltage source, the voltage available at any point in a circuit, the voltage drop caused by a load service within a circuit, and circuit continuity, or completeness.

Analog Voltmeter Design

The basic analog meter illustrated in Figs. 5-3 and 5-4 is made into a voltmeter by simply connecting it across a voltage source. However, to bring the needle movement within the range of the voltage being measured, a resistor must be inserted in the line to the needle movement (Fig. 5-5). Analog voltmeters have as much as 1,000 ohms per volt resistance in the coil circuit. This allows for very slight current flow through its windings.

Digital Voltmeter Resistance

Testing most computerized engine control systems requires the use of a digital voltmeter with a high input *impedance* (*resistance*) rating of 10 megohms or higher. This means that the digital voltmeter has a minimum of 10 million ohms of internal resistance. A typical analog meter has only about 10,000 to 12,000.

Many microcomputer circuits have high resistance values that control the current flow. During a test, placing the leads of an analog meter, with its lower internal resistance, across a high resistance microcomputer circuit could easily cause a short. In other words, the meter's circuit offers an easier electrical path than the one being tested. The resulting excessive current flow can damage a microcomputer component.

Voltmeter Applications

A voltmeter is always connected across a circuit to read available voltage (Fig. 5-6). This is called a *shunt* connection. In this case, little current will flow through the voltmeter due to its internal resistance.

As you can see in Fig. 5-6, the voltmeter is connected so that it parallels the existing circuit. In other words, the positive voltmeter lead connects to the (+) side of the circuit and the negative lead to the (−) side. Reversing the leads will cause the me-

ter needle to move downscale and possibly damage it. Moreover, for greatest accuracy when using a voltmeter, select a voltage range so that the meter reading is in the mid-scale position whenever possible.

A voltmeter can also be used to measure the voltage drop across a load device or conductor. *Voltage drop* is the using up of voltage, caused by the current flow through a resistance unit. Moreover, any increase in either resistance or current flow will intensify the voltage drop.

To check the amount of voltage drop, connect the voltmeter leads across the points to be measured (+ to + and − to −). The voltmeter should now sense and display the voltage drop across the resistance unit as long as current is flowing in the circuit (Fig. 5-7).

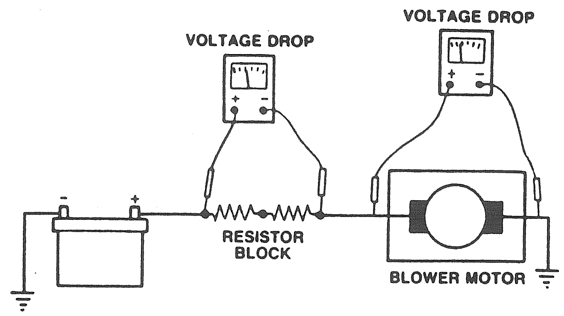


FIGURE 5-7
Voltmeter connected to measure voltage drop. (Courtesy of Chrysler Motors Corp.)

5-3 AMMETER

The *ammeter* is a device that measures the amount of current flowing in a circuit. The instrument can determine if current is in fact flowing (i.e., the circuit has continuity), or if the flow is excessive due to a short in the circuit. In any case, the meter measures the flow in amperes or amps.

Ammeter Design

To make a simple analog voltmeter into an ammeter, a low-voltage internal shunt resistor is added across the terminals of the meter coil (Fig. 5-8). The external leads also connect to the shunt. The shunt resistor protects the small meter coil from excessive current flow.

The resistance of the shunt resistor is very low but high enough to act as a low-resistance internal conductor in parallel with the meter movement. Therefore, the meter coil has to handle and react to only a small part of the current flow in a given circuit.

Many ammeters have a knob or switch that moves shunt resistors of different values into parallel with the meter coil. This changes the proportion of the current flow through the coil and creates different ranges of amperage values that the meter can safely measure.

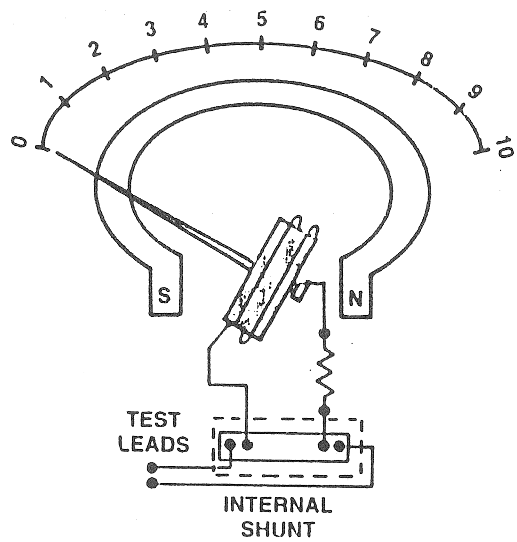


FIGURE 5-8
Ammeter basic design. (Courtesy of Ford Motor Co.)

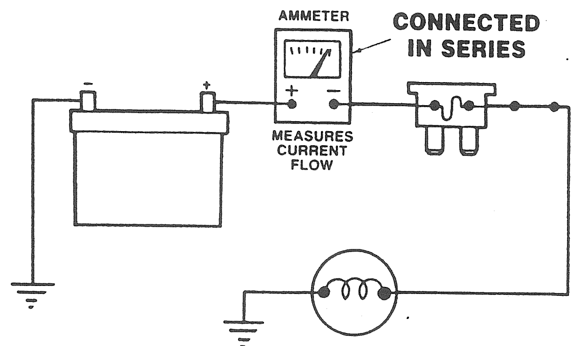


FIGURE 5-9
Ammeter connected in series with a circuit. (Courtesy of Chrysler Motors Corp.)

Ammeter Applications

The ammeter is always connected into a circuit or in series; it is never connected across components (Fig. 5-9). If the meter is connected across a component, its resistance is eliminated. In this case, the circuit current flow is shunted around the component. As a result, the meter may burn up due to excessive internal current flow.

In addition, never use an ammeter in a circuit that is carrying more current than the meter is designed to handle. It is all right in such a situation to use external shunts to lower the current flow to within the meter's range. Finally, always use the leads that are supplied with the ammeter since they form a critical part of the design makeup of the unit.

The use of an ammeter in testing components or circuits of computerized engine control systems is very limited. However, some manufacturers do call for the use of an ammeter for adjustment of certain components that are in sensitive circuits. In this situation, never use an ammeter with high resistance for this purpose. Adjustments made with such a meter in the circuit will be faulty because the total circuit resistance will change when the meter is disconnected.

Ammeters suitable for this purpose have an internal resistance of only about 0.01 ohm. This provides less than a 0.1 voltage drop across its leads with 10 amperes of current flowing in the circuit.

5-4 OHMMETER

An *ohmmeter* is an instrument that measures the resistance (in ohms) of a load device or conductor. The design of an ohmmeter's movement in an analog unit is somewhat different from that for a voltmeter or ammeter (Fig. 5-10). The ammeter still uses a D'Arsonval movement, but its also has a separate power source plus a resistor connected in series with the coil.

When the ohmmeter leads are connected together, as shown in Fig. 5-10, or to a device being tested, current from the meter's power source flows through the circuit and moveable coil. The power source can be either a small battery or alternating current. Because the source voltage and the meter's internal resistance are known, the current flow through the coil is determined by the resistance of the load device being tested. As a result, current flow through the meter coil is indicated on the meter scale as a resistance measurement.

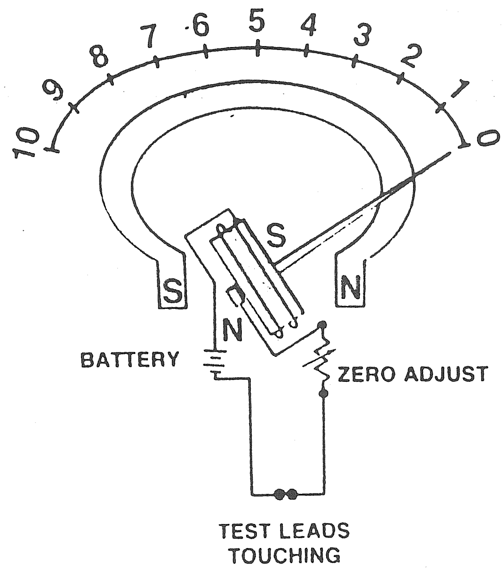


FIGURE 5-10
Ohmmeter design. (Courtesy of Ford Motor Co.)

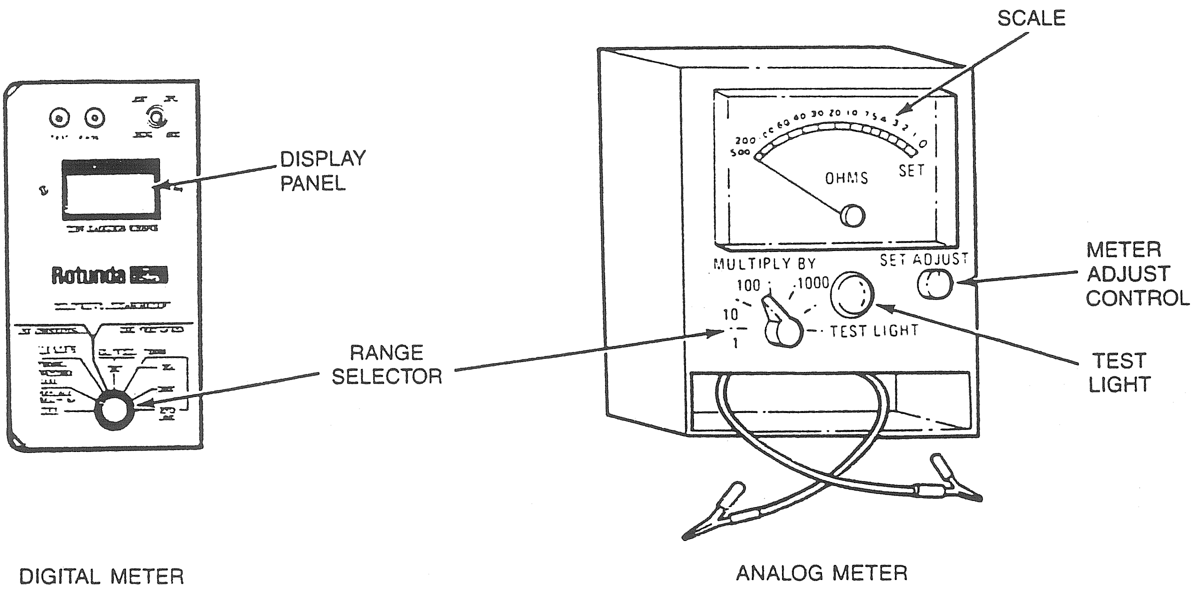


FIGURE 5-11
Design of digital and analog ohmmeters. (Courtesy of Ford Motor Co.)

Notice in Fig. 5-10 that the Ohm scale reads from right to left, just opposite to the one on either the voltmeter or ammeter. The needle, when the meter is not in use, rests against the left or full-scale side. The logic of the system is that when the leads are not connected to a circuit, the needle indicates *infinite resistance*, or a full-scale reading clear to the left. When the leads are connected together, the meter should read *zero resistance*, and the needle should be clear to the right.

Like voltmeters and ammeters, the ohmmeter usually has several scales to read from. A range selector switch determines which scale the operator will use for test purposes (Fig. 5-11). The lower the selector position number the operator can use, the more precise will be the reading taken.

The switch itself inserts different ranges of resistance into the coil circuit. The actual resistance shown on the meter scale is multiplied by the range selector number. For example, if the range selector knob is set at 100 and the needle points to 2, the resistance reading is 200 ohms.

Ohmmeter Calibration

Before using most ohmmeters, the meter needle has to be zeroed, that is, *calibrated to read zero* in any selector range used. This is due to the fact that the voltage of the battery inside the meter will weaken with age and change with temperature. Even the AC voltage used in some meters can vary.

To calibrate an ohmmeter in a given range, connect the two test leads together. The meter should read zero resistance. If it does not, move the calibration, or set adjust, knob until the needle indicates zero ohms. The meter will now provide accurate test measurements.

Digital Ohmmeter

On a digital ohmmeter, the resistance measured is converted inside the unit to a numerical output that is shown in the display window. Digital meters are self-calibrating and therefore do not have an adjusting knob (see Fig. 5-11). Digital meters also have various ranges just like the analog units.

Some microcomputer engine control systems require the use of a digital ohmmeter with at least 10 megohms impedance for testing purposes. The reason for this is that most analog meters use a 9-volt battery as their power source. This is a higher voltage than that supplied by the microcomputer to a number of resistance units or circuits. If an analog meter is used to test a low-voltage circuit such as this, its internal power source is too high. This can result in excessive current flow, which can cause a resistance unit or microcomputer circuit to burn out.

Ohmmeter Applications

When measuring resistance with an ohmmeter, the load device or conductor has to be isolated by disconnecting it from the circuit. *It is imperative that no circuit current be flowing through the device being tested, or the ohmmeter will be damaged.*

To measure the resistance of a typical resistance unit, the leads of the ohmmeter are connected across the item (Fig. 5-12). This type of connection looks similar to the parallel connection used with a voltmeter. However, because there is no system voltage applied to the ohmmeter, it is not really a parallel circuit.

Instead, the self-contained voltage in the ohmmeter creates current flow through a circuit that consists of the meter movement and the resistance unit being tested. Thus, the ohmmeter provides a complete series circuit.

An ohmmeter reading can pinpoint a high-resistance or a low-resistance problem. If the ballast resistor reading in the example shown in Fig. 5-12 is very high or indicates infinity, the unit has high resistance or is open. A reading of zero shows continuity but no measurement of resistance. The resistor in this case is shorted out.

A reading between zero and infinity is the unit's actual resistance to current flow. To determine the actual resistance of the device, multiply the scale reading by the selector knob number.

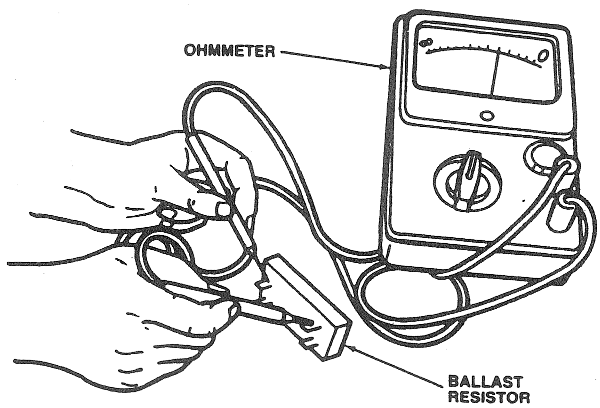


FIGURE 5-12
Testing resistance with an ohmmeter. (Courtesy of Chrysler Motors Corp.)

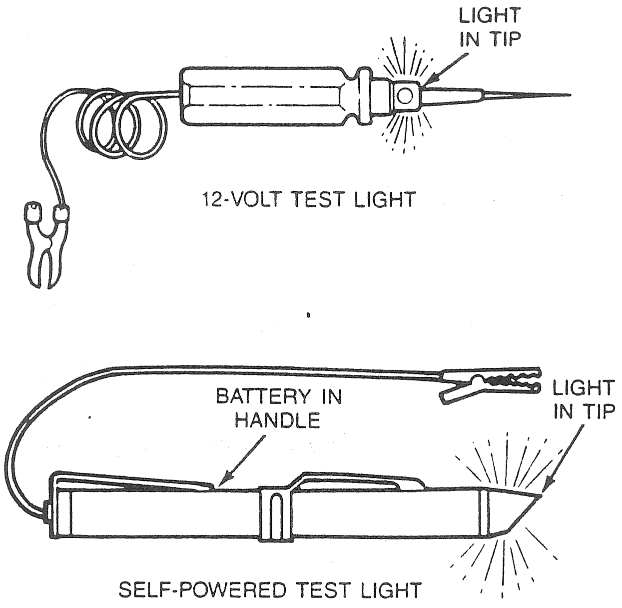
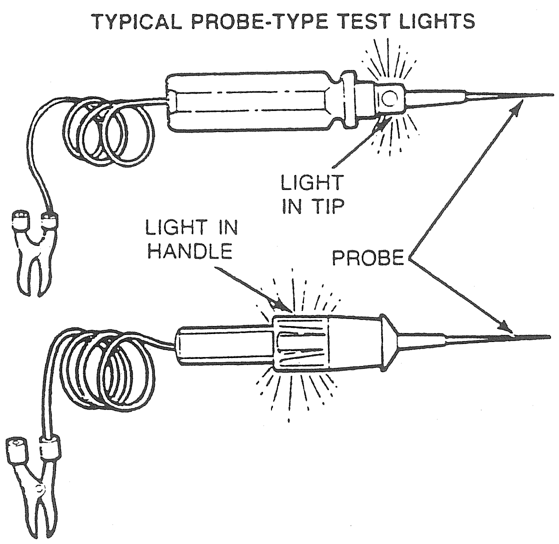


FIGURE 5-13
Test light continuity testers. (Courtesy of Ford Motor Co.)

5-5 CONTINUITY TESTERS AND JUMPER LEADS

There are three different kinds of continuity testers. The most accurate but most expensive is the ohmmeter, described in the last section. The other two are the 12-volt test light and the self-powered test light (Fig. 5-13). These units light up when there is continuity in a circuit or a component is being tested.

FIGURE 5-14
Types of 12-volt testers. (Courtesy of Ford Motor Co.)



12-Volt Test Light

The *12-volt test light* checks for electrical power in any given point in a circuit by illuminating. If the bulb does not light during a test, the circuit is open, and no current is flowing.

Moreover, once you are familiar with the brilliance of the test light bulb in a normal circuit, high resistance can be recognized by its effect on lamp intensity. As the current drops in a circuit due to high resistance, the test light bulb will glow less brightly.

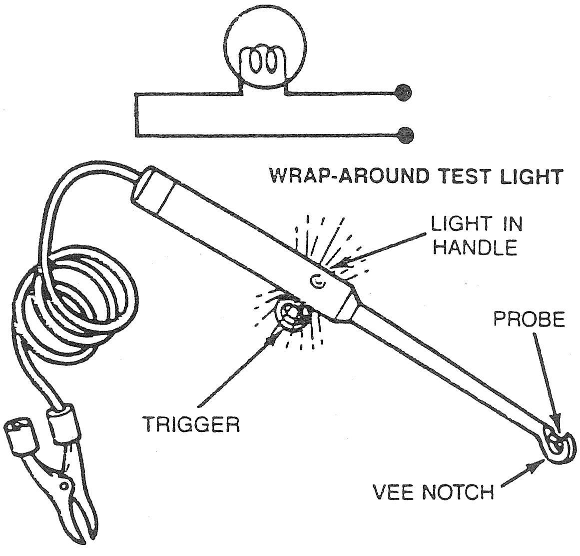
The 12-volt test light depends on the vehicle's battery to power the circuit during a test. Therefore, the battery must be charged sufficiently, or the test results may indicate high circuit resistance.

12-Volt Test Light Design

Manufacturers produce 12-volt testers with different bulb locations and tip designs (Fig. 5-14). Thus, the testers can be used on different types of installations, such as connectors, bare wires, insulated wires, or even wires within harnesses.

Most test lights have a sharp probe tip that can be inserted through the wire insulation for testing. It is important to keep the probe tip sharp to minimize the damage to wire insulation.

To check the tester before use, briefly touch the clip to one battery post and the probe tip to the other; the bulb should burn brightly. A 12-volt tester is not sensitive to the polarity of the battery or a circuit and can be connected with either the tip or clip on a ground. However, the alligator clip is considered the ground side of the tester.



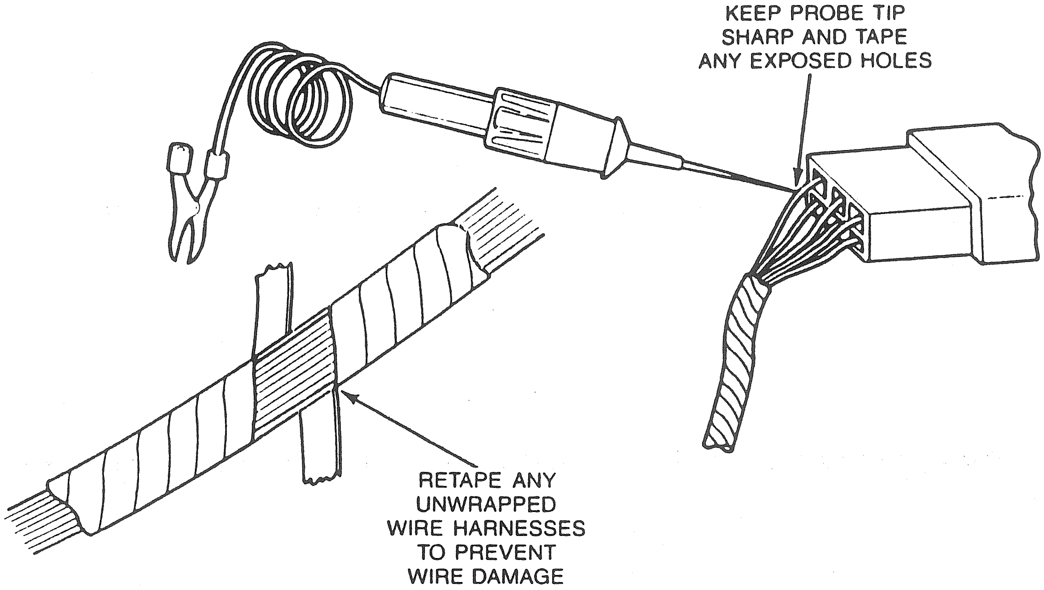


FIGURE 5-15
Typical 12-volt tester usage. (Courtesy of Ford Motor Co.)

12-Volt Test Light Applications

To use the tester to check a particular circuit, attach the alligator clip to a good ground, and then use the tester tip to probe the wire or terminal (Fig. 5-15). If the test light burns, the circuit has power. If the test light does not glow, the circuit is open. To locate the opening, move the test light successively back up the circuit toward the battery or power source until its bulb lights.

When the test is complete, make sure to tape all the holes in the insulation or cover the damaged areas with nonacetic Room Temperature Vulcanizing (RTV) compound.

Caution: Do not use a test light tip to probe electronic ignition or secondary coil cables. Moreover, never pierce wiring on microcomputer-controlled systems unless specifically instructed to do so.

A 12-volt test light can be substituted for a blown fuse to locate the cause of a short to ground (Fig. 5-16). In this case, the test light limits the current flowing in the circuit. If the light continues to burn with all the load devices in the circuit disconnected, there is a short to ground. The various harness connectors should then be unplugged one at a time, working back from the farthest load device in the circuit, until the light goes out. When the light quits burning, the short will be located somewhere between the last unplugged connector and the previous one.

Self-Powered Test Lights

The *self-powered test light* differs from the 12-volt unit in that the former carries its own battery as the source of power (Fig. 5-17). Its primary use is to test for continuity through a component or part of a circuit. However, the light can also be used to check for shorts to the vehicle body or frame.

Since the self-powered light carries its own power source, whatever unit is being tested has to be isolated from the vehicle battery so there is no voltage present. If this tester is connected to 12 volts, the 1-½ volt bulb will burn out.

The self-powered test light serves a dual purpose. It can be used to check for either an open or a short circuit when power is isolated from the circuit. The self-powered test light glows any time it is connected to a complete circuit (Fig. 5-18). However,

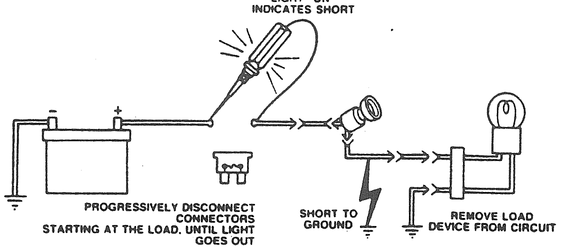


FIGURE 5-16
Test light used to locate a short to ground. (Courtesy of Chrysler Motors Corp.)

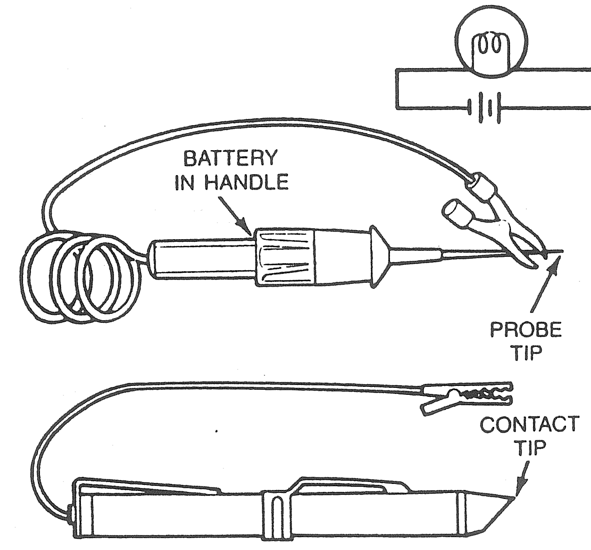


FIGURE 5-17
Typical self-powered test light. (Courtesy of Ford Motor Co.)

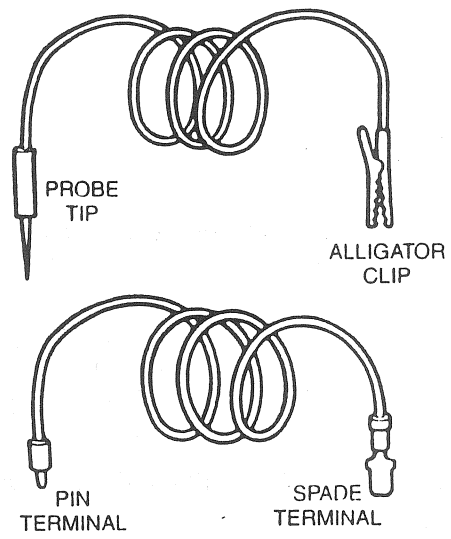


FIGURE 5-19
Typical jumper leads. (Courtesy of Ford Motor Co.)

the light will not burn, due to its low voltage, if the circuit or load devices have too much resistance.

Caution: Do not test microcomputer circuits and components that operate on milliamperes. The current from the self-powered test light will damage them.

Jumper Leads

A *jumper lead* or *wire* is the simplest type of electrical troubleshooting tool (Fig. 5-19). Jumper leads allow the technician to temporarily bridge a suspected opening or break in a circuit. Technically then, a jumper lead is also a simple continuity tester.

The jumper lead is nothing more than a length of wire with a probe tip, various types of wiring clips, or connector terminals installed on either end, as shown in Fig. 5-19. As an aid to troubleshooting, it is a good idea to have several jumper leads available with different end configurations.

The jumper lead in use bypasses a portion of a circuit (Fig. 5-20). In this example, the jumper lead is used to bypass a switch and apply power directly to the load device. If there is power to the switch, and if the circuit works properly with the jumper lead in place but does not work with it removed, the switch is open.

Jumper leads can be used for several other purposes. For instance, the lead can be used to provide a good ground for a circuit or load device. In addition, jumper leads can be used to bench test a load device to confirm its proper operation.

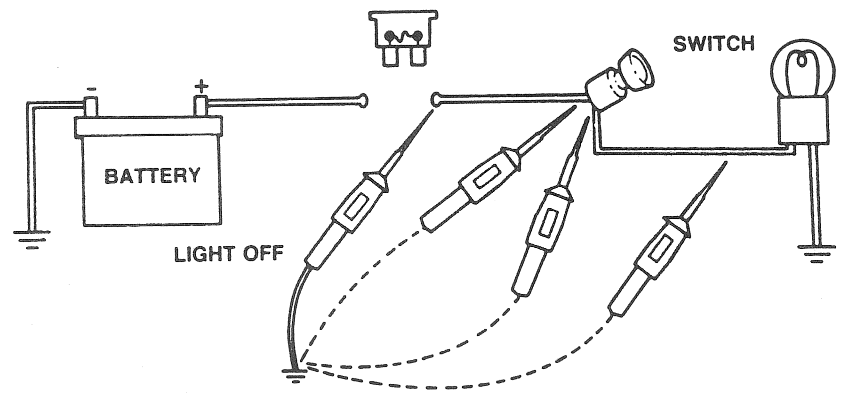


FIGURE 5-18
Using the light to check for an opening or for continuity. (Courtesy of Chrysler Motors Corp.)

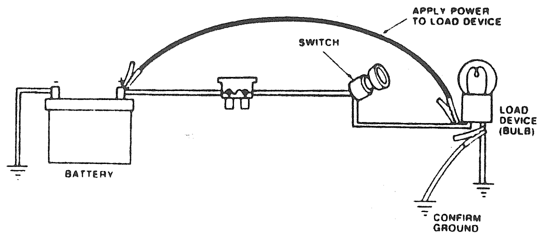


FIGURE 5-20
Jumper lead used to bypass a portion of a circuit. (Courtesy of Chrysler Motors Corp.)

Caution: Be careful when handling a positive (+) jumper lead. If it touches a ground, it will cause a short. Moreover, never use a jumper lead to bypass a load device. This will cause excessive current flow in the circuit, which will overheat the wire or open a fuse, circuit breaker, or fusible link.

5-6 ENGINE PERFORMANCE TEST EQUIPMENT

Before discussing the different types of test equipment used to check electronic circuitry, it is important to stress that most computerized engine control malfunctions are *not* due to problems in the microcomputer. In other words, the cause of the problem is most likely one or a number of simple items related to engine performance, such as a fouled spark plug, open plug wire, disconnected or leaking vacuum hose, burned valve, or a dirty carburetor, to name a few. Any one of these will give a microcomputer a faulty input signal in one way or the other. Therefore, its output signal to any number of actuators cannot be correct, and further malfunctions develop.

For this reason, this section reviews the various types of test equipment used to check systems or components relating to engine performance. These include the compression tester, vacuum gauge, vacuum pump, timing light, spark tester, tach/dwell meter, oscilloscope, and exhaust gas analyzers.

Compression Tester

A *compression tester* is an instrument that measures the ability of a piston to compress the air/fuel mixture within the cylinder. An engine requires good and equal compression pressure in all cylinders for two reasons. First, if compression pressure leaks past worn rings or valves or around the head gasket or spark plug, engine power is lost.

Second, low or no cylinder compression causes excessive amounts of air to enter the exhaust, which interferes with normal microcomputer operation. During feedback operation, the microcomputer monitors the air/fuel mixture by measuring the remaining oxygen in the exhaust gases via the oxygen sensor. If there is excessive air remaining in the exhaust due to low compression or any type of misfire, the microcomputer senses excess oxygen and will enrich the air/fuel ratio. This compounds the problem of a loss of engine power by over-enriching the mixture to the remaining good cylinders.

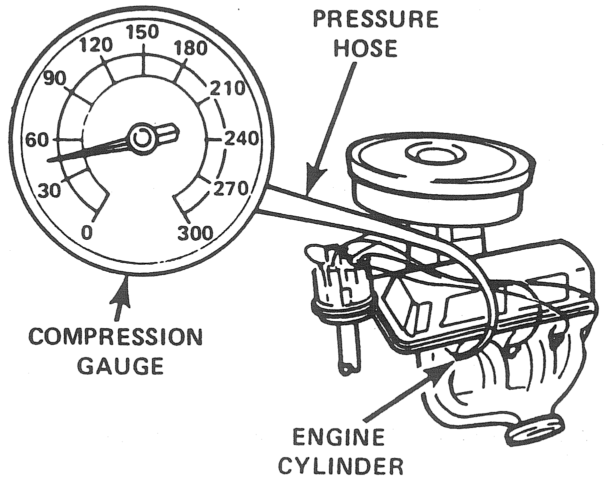


FIGURE 5-21
Gauge used to measure the amount of cylinder compression. (Courtesy of Chrysler Motors Corp.)

A typical compression gauge for gasoline engines (Fig. 5-21) is able to measure high pressures of up to 300 pounds per square inch (psi), or 2,067 kilopascals (kPa). For a diesel engine, the gauge has to read up to 800 psi (5,512 kPa). The most accurate gauge design has a threaded adapter that fits into the spark plug hole. A hose connects the adapter to the gauge.

Another gauge design has an extension fitted with a flat or tapered rubber tip that fits into the spark plug hole. This gauge is used by holding the tip firmly into the plug hole during the test. Consequently, the gauge is harder to use and is usually not as accurate.

Vacuum Gauge

A *vacuum gauge* is a device that measures the ability of a piston to create a low pressure or vacuum within the cylinder and intake manifold (Fig. 5-22).

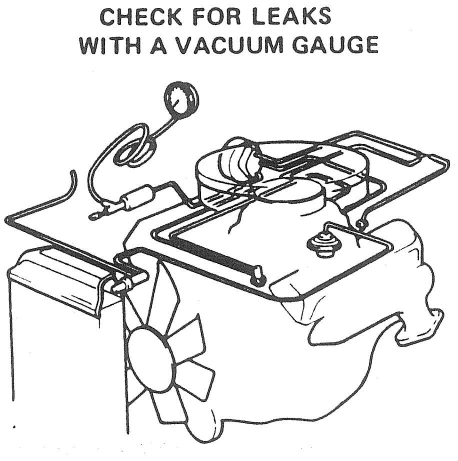


FIGURE 5-22
Typical vacuum gauge installation. (Courtesy of Chrysler Motors Corp.)

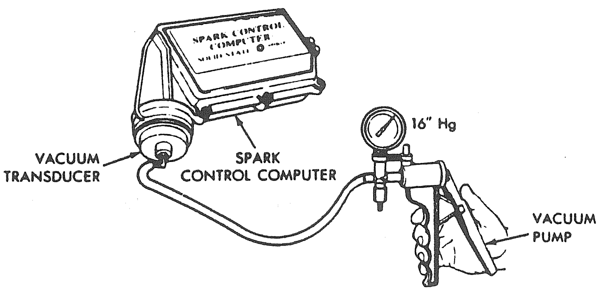


FIGURE 5-23
Vacuum pump. (Courtesy of Chrysler Motors Corp.)

The manifold vacuum, although used to operate a number of pneumatic devices, is necessary primarily to provide a pressure differential between the atmosphere and the cylinder. This is needed to force the air/fuel mixture, via the intake manifold, into all the cylinders. If a loss of vacuum occurs due to a leak, not only is the movement of the mixture to the cylinders affected, but the air/fuel ratio is also leaned out.

The vacuum gauge has a scale with divisions marked off in inches of mercury (Hg), ranging from 0 to 30 inches Hg (0 to 76 millimeters Hg). The movement of the needle on this scale indicates the difference in pressure between the atmosphere and what is in the intake manifold.

All gauge readings are dependent on altitude and must be adjusted for areas above sea level. For example, with every 1,000 feet (305 meters) above sea level, the vacuum gauge reads low by 1 inch (25.4 millimeters) Hg. In this situation, 1 inch Hg will have to be added to any gauge reading taken in order for it to be accurate.

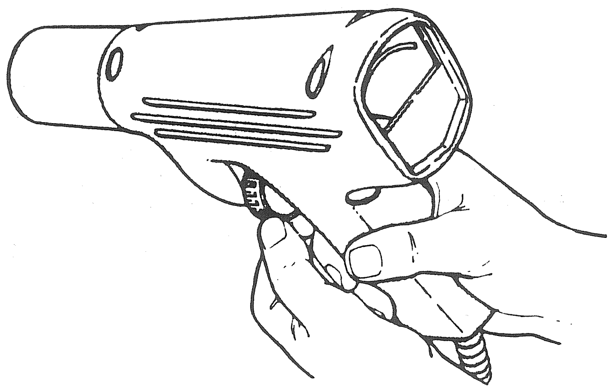


FIGURE 5-24
Power timing light. (Courtesy of Chrysler Motors Corp.)

Vacuum Pump

The *hand-operated vacuum pump and gauge assembly* (Fig. 5-23) is a very useful tool. This device can test the serviceability of most pneumatic controls such as a vacuum transducer, delay valve, vacuum motor, or vacuum advance diaphragm with the unit on or off the vehicle.

The pump shown in Fig. 5-23 consists of a vacuum gauge, vacuum pump, and release trigger. The gauge connects externally via a hose to the component being tested and internally to the vacuum pump. The gauge dial scale is marked off from 0 to 30 inches Hg and 0 to 76 millimeters Hg.

The vacuum pump is inside the main housing. The pump handle mechanically activates this pumping mechanism. It, in turn, evacuates the air from the test component, thus creating a partial vacuum.

The release trigger has one important function. That is, it vents all or part of any vacuum built up by the pump into the atmosphere. Therefore, by coordinating the movements of the pump handle and trigger, the technician can easily pump up a specific amount of vacuum within a unit.

Power Timing Light

The *power timing light* (Fig. 5-24) is used to test and set the initial ignition timing and to quickly check the action of the advance devices. In other words, this unit can measure the amount of spark advancement provided by the mechanical and vacuum advance mechanisms or the electronic control unit. This particular light is powered by the vehicle battery and has an inductive pickup that usually clamps around the number one spark plug cable.

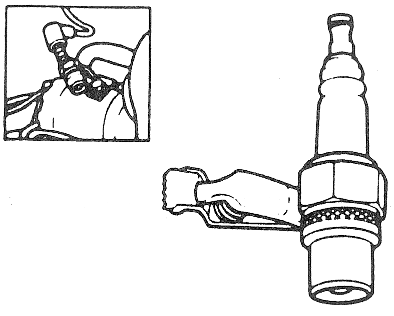


FIGURE 5-25
Spark tester. (Courtesy of Ford Motor Co.)

The light assembly also has a timing advance meter and control knob. The advance meter is built into the back of the light and has a scale with degree markings that are used to measure the exact amount of spark advancement.

The knob controls the electronic timing unit within the light, so it can make the light flash before or after the spark plug fires. By doing so, the action of the electronic timing light makes it appear that the crankshaft timing mark moves backward along the engine degree scale in relation to knob rotation.

Using this light, and with the engine operating at a specified speed, the technician can bring the timing mark back into alignment with the initial timing indication on the degree scale. The meter on the light shows the exact amount of spark advancement for which the light has compensated. The light then lets the technician read the total spark advancement much more accurately than possible by just viewing the timing mark movement of the engine degree scale.

Spark Tester

A *spark tester* is a device that is used to check the secondary output voltage of the ignition system without removing a spark plug from the engine. The tester (Fig. 5-25) lets a technician see if the ignition coil can create enough energy to arc across a very wide gap, yet the tool does not allow the system to operate open circuited.

This is important for two reasons. First, electronic ignition systems can produce very high voltages when open circuited. If a technician holds the coil wire too far away from a ground while testing output voltage, he or she can receive a shock if the cable's insulation is defective.

A number of manufacturers do not want their ignition systems operated open circuited because this can damage the coil or other components. A typical example of this problem can occur in a General Motors high energy ignition (HEI) system. An open secondary circuit can cause a high voltage surge. Moreover, in its attempt to reach a ground, the voltage surge will pass through the integral ignition module and destroy it.

The tester, which is grounded via the alligator clip, prevents excessively high secondary voltage by supplying a large but calibrated gap opening between two plug electrodes. The coil has to produce high voltage to bridge the air gap but not enough to cause damage.

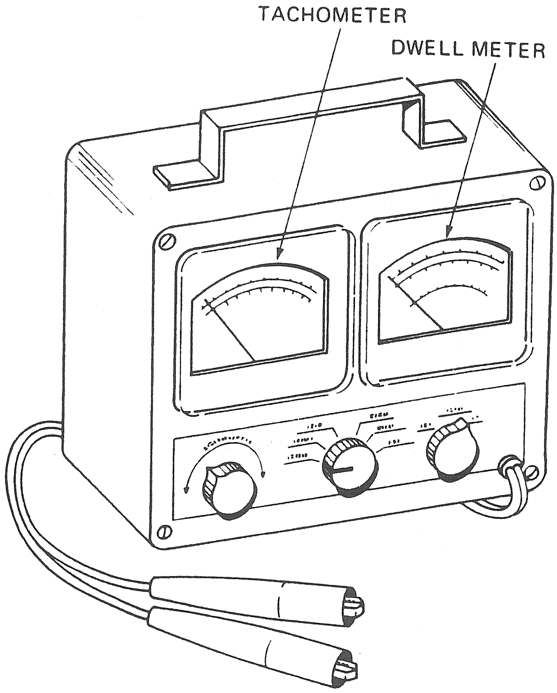


FIGURE 5-26
Typical tach/dwell meter.

Tach/Dwell Meter

A *tach/dwell meter* is an instrument that combines both a tachometer and a dwell meter into a single unit (Fig. 5-26). Both of these instruments are special types of analog voltmeters. For test purposes, the unit is connected to the ignition primary circuit. With the engine operating, the primary circuit provides an on-off-on voltage signal to the meter. The meter's internal circuitry converts this signal to a varying amount of current flow through the D'Arsonval instrument coil.

The tachometer scale has divisions to show engine speed in revolutions per minute (rpm). As engine speed varies, the primary circuit's on-off-on

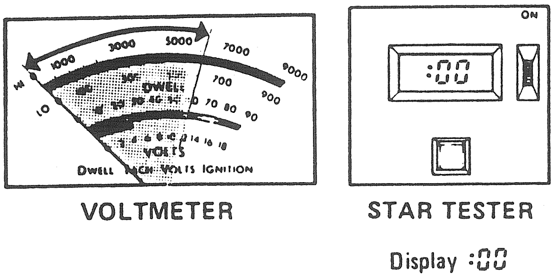


FIGURE 5-27
Use of a dwell meter or voltmeter to read service codes. (Courtesy of Ford Motor Co.)

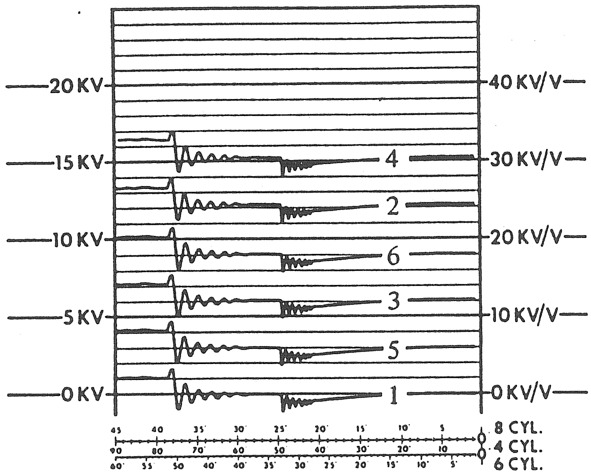


FIGURE 5-28
Typical oscilloscope screen. (Courtesy of Sun Electric Corp.)

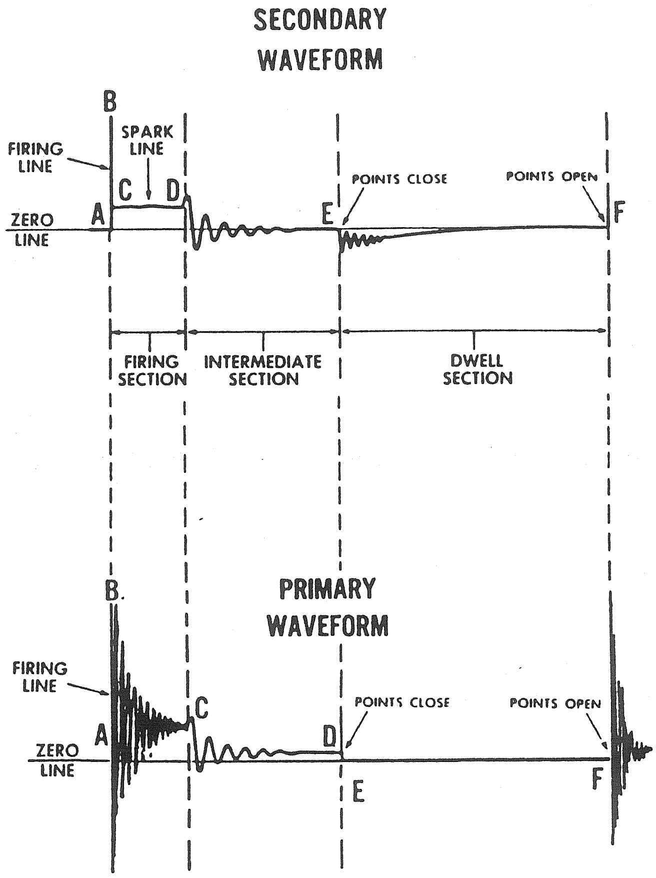


FIGURE 5-29
Secondary and primary waveform patterns of a conventional ignition. (Courtesy of Sun Electric Corp.)

voltage signal changes. Consequently, the tachometer needle moves to a different location on the engine speed scale.

The dwell meter scale has markings that show degrees of distributor shaft rotation. The position of the dwell meter needle then indicates, in terms of degrees of distributor shaft rotation, just how long current is allowed to flow in the ignition primary circuit. In the conventional contact point ignition system, dwell is determined by the opening and closing of the points. In electronic systems, dwell is determined by circuitry in the ignition module, or by the microcomputer in a number of computerized engine control systems.

The dwell meter is also used now for several other types of tests. For example, General Motors and some other manufacturers specify the use of a dwell meter to test the operation of mixture control and other solenoids that operate continually with varying duty cycles. The *duty cycle* is the percentage of solenoid or component on-time during an on-off cycle.

In addition, some manufacturers specify the use of a dwell meter or an analog voltmeter to read service codes stored in microcomputer memory (Fig. 5-27). In this case, the meter is used in place of an automatic readout unit like a STAR tester. The dwell meter or voltmeter indicates a service code as pulsing movements of the instrument needle. A code 24, for example, registers as two fast needle pulses, a two-second pause, and then four additional fast needle pulses. Normally, about a four-second pause separates service codes when more than one is in microcomputer memory.

Oscilloscope

The *oscilloscope* is an instrument designed to aid in diagnosing ignition system malfunctions. Through its proper use, the technician can readily locate abnormal conditions within the ignition system by comparing the patterns observed on the scope screen (Fig. 5-28) with those of a trace from a nor-

mal operating system. In addition, the oscilloscope can indicate malfunctions in the alternator and often other abnormal conditions such as a high combustion chamber temperature, high pressure, or an incorrect air/fuel ratio.

The oscilloscope itself converts the complex electrical voltages developed during the ignition cycle into a graph-like picture. This picture (waveform pattern) represents all phases of the ignition cycle at the same instant they occur in the operating cycle (Fig. 5-29). The waveform permits accurate observation of the factors affecting ignition system operation that were once assumed in theory only. Moreover, since a properly operating ignition system provides a characteristic pattern, any deviation from it indicates some type of malfunction.

Each part of the waveform represents a specific phase of ignition system operation. For the purpose of understanding it, a pattern is divided into three sections: (1) the firing, (2) the intermediate, and (3) the dwell.

An oscilloscope screen can display both secondary and primary patterns (see Figs. 5-28 and 5-29). To do this, the screen is laid out in kilovolts (kV) to permit accurate voltage measurements. Each vertical division at the left side of the screen represents 1 kilovolt (1,000 volts). Each mark at the right side represents 2 kV.

The secondary waveform is more informative for showing overall ignition system operation than the primary pattern. However, ignition system problems that affect the intermediate or dwell section of the pattern will be indicated in both types of waveforms. Therefore, a primary pattern is basically used to permit a scope test when secondary circuit connections are not accessible, observe point conditions or actions of switching transistors, and provide a dwell pattern of greater clarity at the discretion of the operator.

With either type, the waveform is a picture of voltage in relationship to time. All vertical movement of the trace represents voltage—one polarity when the trace is above the zero kilovolt line and the opposite when it is below this line. Therefore, an oscillating pattern above and below the zero line represents AC voltage. Any vertical trace can be measured by comparing it to the graduations on the scope screen.

Horizontal movement of the trace represents time. On newer scopes, this is measured by screen markings in milliseconds. On older models, the divisions were in terms of distributor shaft degrees of rotation.

Figure 5-29 illustrates the ideal waveform for a conventional ignition system. The patterns for electronic systems are similar, but there are some differences. Patterns for electronic systems can be found in Chapters 6-11.

Exhaust Gas Analyzers

There are three types of *exhaust gas analyzers* in use, the two-, three-, and four-gas models. The two-gas (infrared) analyzer is built for use on vehicles without catalytic converters. The three- and four-gas units are designed for use on all vehicles.

An *infrared analyzer* is a precise instrument for measuring the carbon monoxide (CO) and hydrocarbon (HC) levels in a vehicle's exhaust (Fig. 5-30). The analyzer operates on the principle of passing a single beam of infrared light through a gas sample taken from the tailpipe. The beam is chopped by a rotating wheel containing optical fibers that derive a signal proportional to the percentage of CO and HC in the sample. These data are electronically processed to separate the carbon monoxide and hydrocarbon signals and apply them to analog-type meters on the analyzer console.

The sample is usually taken via a probe inserted into the tailpipe. However, some vehicles with catalytic converters have a probe access hole in front of the converter to permit the use of this analyzer. In either case, the probe connects to the analyzer through a sampling hose and water trap that removes moisture.

The analyzer measures CO content as a percentage by volume. For instance, a one percent CO reading means that one percent of the total volume of exhaust gas is CO. Some of the most likely causes of excessive CO levels are the carburetor idle mixture is set too rich, the carburetor circuitry is malfunctioning, the choke is malfunctioning or misadjusted, the air cleaner is clogged, the air pump is inoperative, the positive crankcase ventilation (PCV) system is inoperative or clogged, the idle speed is below specifications, the initial timing is incorrect (over advanced), or the emission control devices are inadequately maintained.

HC levels are measured in parts per million (ppm) by volume. For example, a reading of 100 ppm indicates that for every million parts of exhaust gas, 100 parts are HC. Some of the most common causes of excessive HC readings are the cylinder compression is low, there are vacuum leaks, the ignition timing is incorrect, the carburetor is out of adjustment (too rich or too lean), the emission control devices are improperly maintained or adjusted, the spark

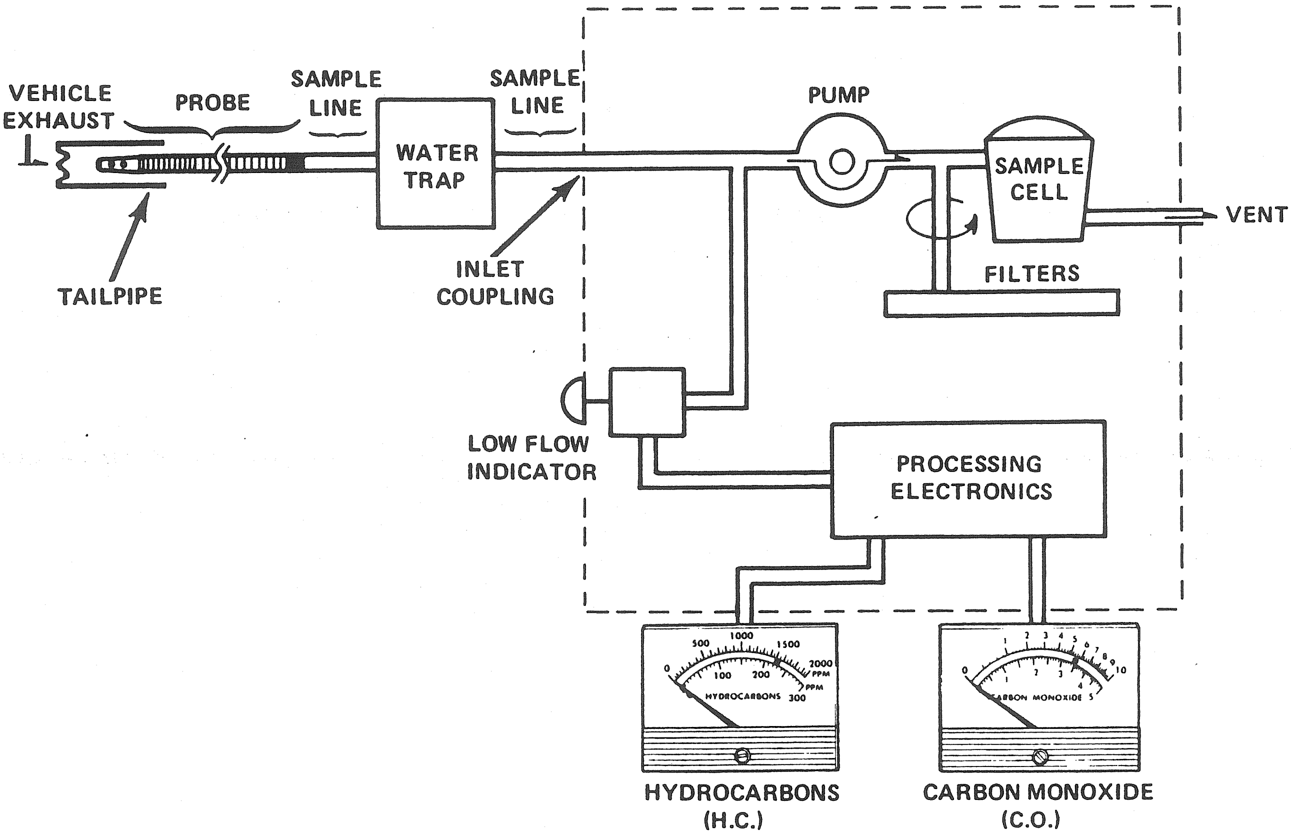


FIGURE 5-30
Typical infrared analyzer design. (Courtesy of Chrysler Motors Corp.)

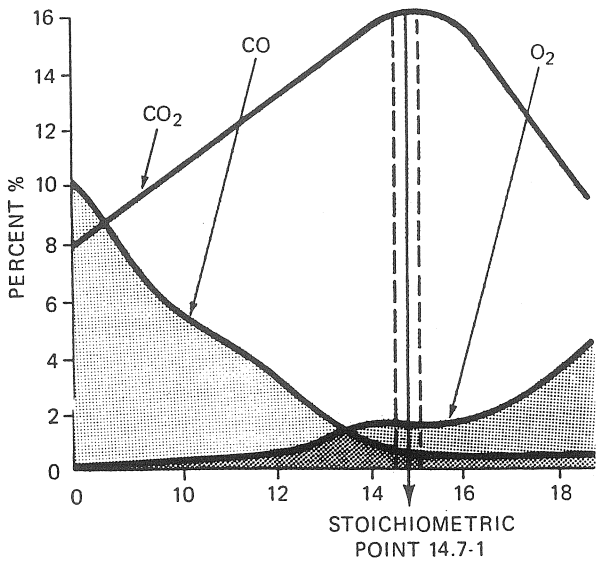


FIGURE 5-31
Oxygen and carbon dioxide levels are indications of the air/fuel ratio.

plugs are fouled, the secondary ignition cable is broken or defective, the distributor cap is cracked, there is a faulty valve or valve train component, or worn rings or valve guide seals are causing excessive oil consumption.

A *four-gas analyzer* has the ability to measure not only HC and CO levels but also oxygen (O_2) and carbon dioxide (CO_2) levels. A *three-gas analyzer* measures HC, CO, and O_2. These analyzers provide the only method now available for checking the air/fuel ratio of vehicles with catalytic converters that have no access plugs. The problem here stems from the ability of the catalytic converter to reduce the HC and CO emissions to acceptable levels even when the carburetor is set incorrectly. In other words, the HC levels do not increase if the carburetor mixture is set too rich or lean because the converter oxidizes the excessive hydrocarbons. If the air/fuel ratio is set too rich, CO levels do increase, but they are not as high as they would be on a precatalytic converter vehicle.

However, O_2 and CO_2 levels are also indicators of the engine's air/fuel ratio (Fig. 5-31). For example, the O_2 level in the exhaust increases signifi-

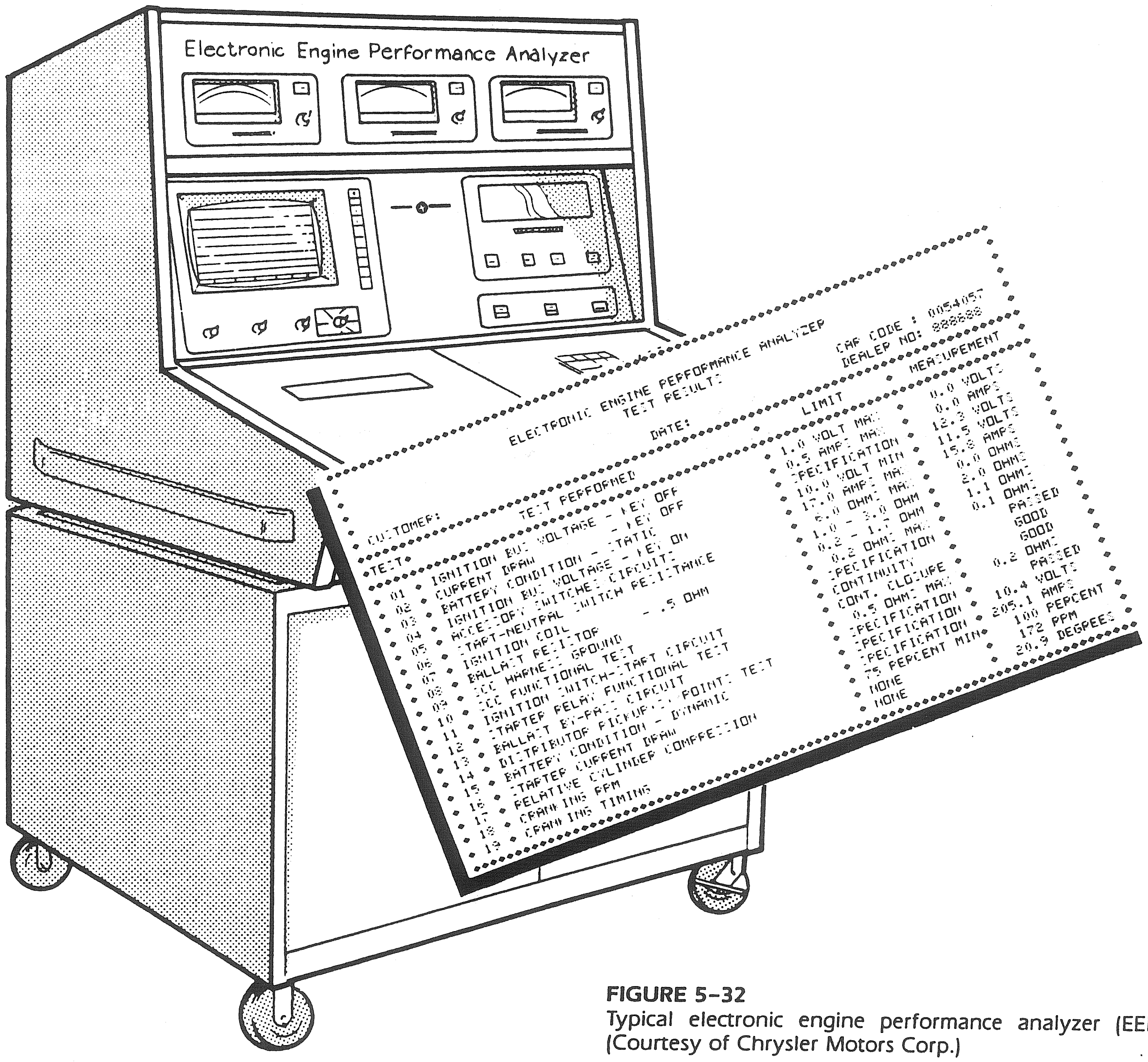


FIGURE 5–32
Typical electronic engine performance analyzer (EEPA). (Courtesy of Chrysler Motors Corp.)

cantly when the air/fuel ratio becomes leaner than 14.7:1. A ratio of 14.7:1 is the *stoichiometric point* or *ideal ratio* at which gasoline burns most efficiently. Therefore, the O_2 level is an excellent indicator of a lean air/fuel ratio.

The CO and O_2 levels can be used to check catalytic converter action. If the O_2 level is above 0.5 percent, the converter is receiving enough oxygen to function. If the CO level is above 0.5 percent, with an O_2 reading of 0.5 percent, the converter is usually not oxidizing the carbon monoxide.

Carbon dioxide levels in the exhaust increase as the air/fuel ratio becomes lean, up to the 14.7:1 ratio. When the air/fuel ratio becomes leaner than 14.7:1, the CO_2 levels decrease.

Electronic Engine Performance Analyzers

A number of equipment manufacturers are producing an *electronic engine performance analyzer* (EEPA). As the complexity of the automobile increases, diagnosis becomes a larger and tougher job. The EEPA was developed to keep pace with the engineering advances that are a result of government regulations and customer needs.

These EEPA machines (Fig. 5–32) are the most up-to-date diagnostic tools available. An EEPA uses computer technology to precisely test engine electrical and performance-related components in a fraction of the time required for traditional testing.

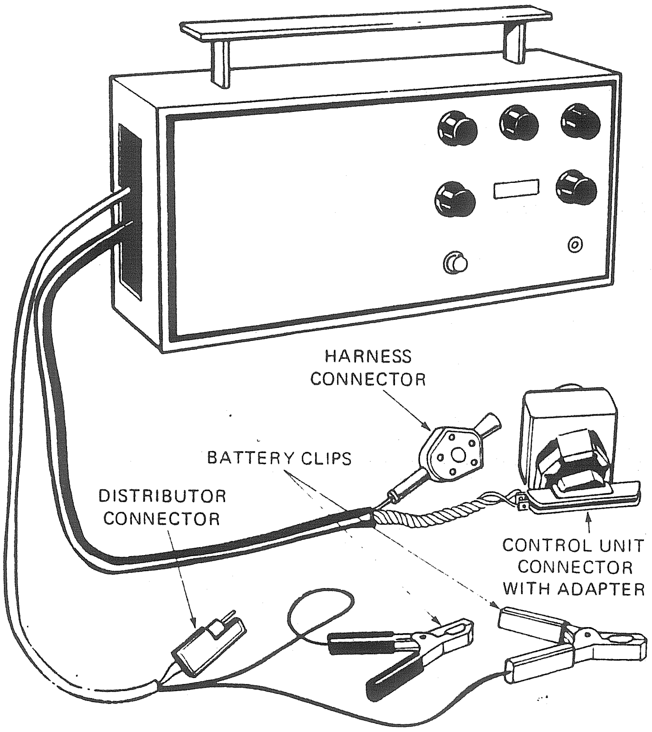


FIGURE 5-33
Typical electronic ignition tester.

One advantage of most EEPA units is that they are easily updated. New model information can be stored in microcomputer memory as it becomes available. Moreover, the modular design of most analyzers gives them the capability of having new functions and tests added as they become available.

Most EEPA units have the same types of instrumentation we have discussed so far. That is, their consoles contain an oscilloscope, voltmeter, ammeter, ohmmeter, tachometer, gas analyzer, and power timing light. These instruments can be used individually by the operator to locate a specific problem, or they can all function as part of a test sequence.

The programmed microcomputer test is performed by the analyzer in a logical sequence. Troubleshooting then becomes very consistent, as the same test methods are used for each vehicle.

Another advantage of these analyzers is that they have a built-in printer. It prints out the results of the programmed test and suggested diagnoses for those components that do not meet specifications. A copy of this report can be used during the writing of the repair order or given to the customer to show him or her how the vehicle is operating.

Electronic Ignition Testers

A few vehicle manufacturers produce a tester for use on their electronic ignition systems (Fig. 5-33). A tester such as this is used to check the operation of the entire system or to test a number of components off the vehicle. The battery clips shown in Fig. 5-33 are used only during off-vehicle testing. Lights on the face of the tester indicate whether components are faulty or serviceable.

There are also a few aftermarket module testers in use. These devices do not check the system on the vehicle but run a number of tests on the ignition module to determine if it is still serviceable. The advantage to the aftermarket tester is that it is usually capable of checking the modules of most current electronic ignition systems in use.

5-7 MICROCOMPUTER ENGINE CONTROL SYSTEM TESTERS

As mentioned, most microcomputer engine control systems have the ability to store service or trouble codes in memory. These codes can be retrieved and read through the use of an analog voltmeter, a dwell meter, or some type of readout tool or scanner. These instruments can be produced for a given microcomputer system or can test a number of systems.

Figures 5-34 and 5-35 illustrate two readout instruments. The first is a self-test automatic readout (STAR) tester used by Ford on its MCU and some EEC-IV systems. The second is a diagnostic readout tool used by Chrysler Motors Corporation

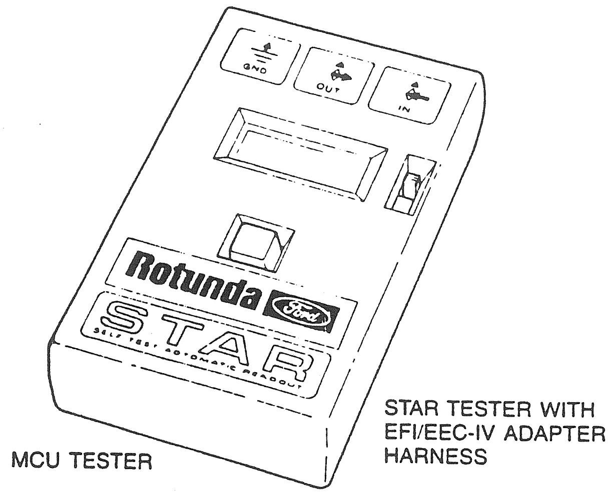


FIGURE 5-34
STAR tester. (Courtesy of Ford Motor Co.)

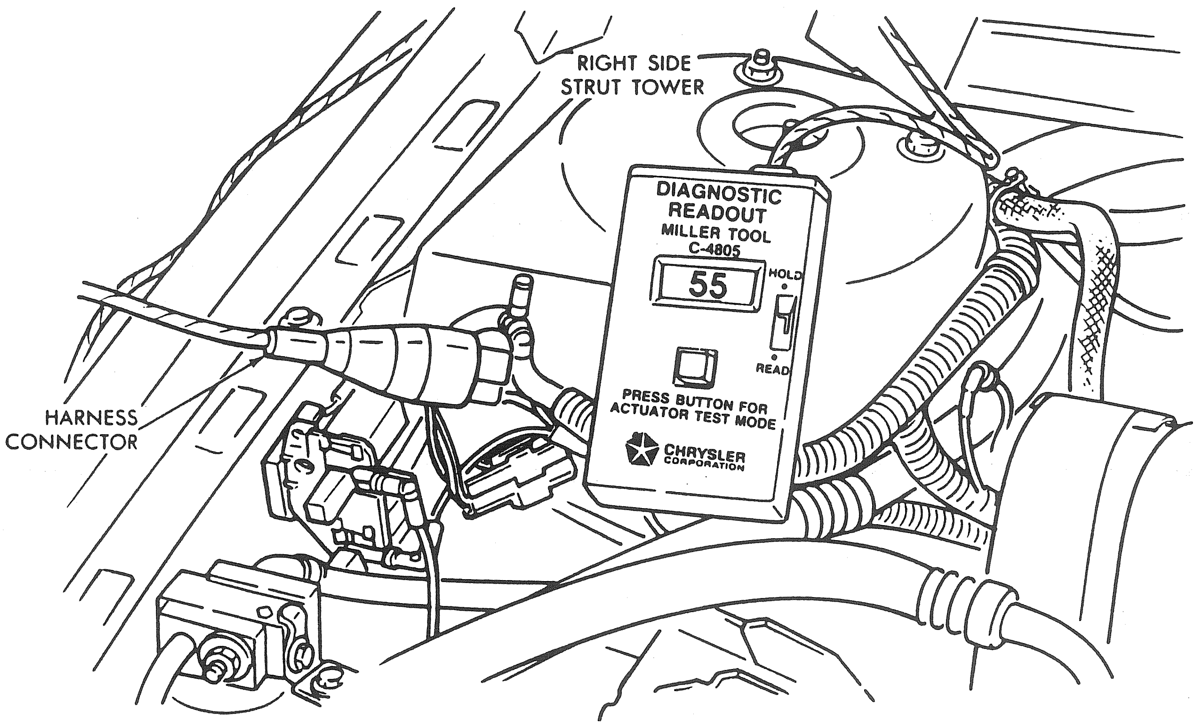


FIGURE 5-35
Diagnostic readout box. (Courtesy of Chrysler Motors Corp.)

on a number of systems.

In both examples, the instrument connects into a system harness connector. Each instrument will then display a service code in a digital format, which will provide valuable information during the troubleshooting of the applicable system.

When a service code appears, it indicates that the microcomputer has recognized an abnormal signal in the engine control system. The service code indicates the results of a failure but does not always identify the failed component. In other words, based on the service code, a technician may need to perform further testing.

Aftermarket Testers

A number of aftermarket testers are available that can check a number of different microcomputer systems. For instance, the Monitor 2000 uses a number of plug-in software cartridges in order to troubleshoot 1981 to current General Motors, Chrysler, and Ford vehicles. The tester is also adaptable to an IBM Personal Computer for data display purposes.

The TIF 1600 on-board computer scanner/printer uses a card to program the unit to fit a certain microcomputer system. This scanner can then run over 100 different tests and take all sensor readings at the same instant. With this device, the technician can evaluate the operation of a vehicle even while driving at varying speeds. The unit also provides a printout for comparing data taken before and after a repair has been made.

Breakout Box

A *breakout box* (Fig. 5-36) is a special diagnostic tool used on Ford's EEC-IV engine control system. The box has both a male and female connector, which permits the installation of the tester between the microcomputer and its wiring harness.

Located on the face of the tester are a series of numbered pins. Each pin connects into a certain circuit within the system via the wiring harness. With this arrangement, the technician can use a digital volt-ohmmeter to check voltage or resistance in various circuits or components of the system as called for by pinpoint tests in the service manual.

CAMS and OASIS

CAMS and OASIS are two rather unique diagnostic tools available to some dealership technicians. Al-

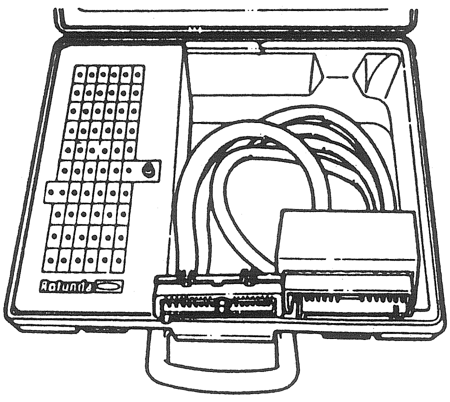


FIGURE 5-36
Breakout box. (Courtesy of Ford Motor Co.)

though both of these systems have been in use for a number of years now, not all dealership service departments have them.

CAMS. General Motors, in cooperation with Electronic Data Systems and IBM Corporation, developed the *Computerized Automotive Maintenance System (CAMS).* CAMS is a computer-based network diagnostic tool that connects the service-bay technician to some very sophisticated equipment. The system was first set up for Buick dealerships, but it is now used to some extent by Chevrolet, Pontiac, and GMC agencies. Cadillac and Oldsmobile will also soon be on-line with this system.

CAMS consists of a mainframe computer and a service-bay processor terminal (Fig. 5-37). The host mainframe computer for Buick is located in Flint, Michigan. This computer is an IBM 4381 with enough memory to record every detail of every electronic system Buick has made since 1981, along with each detail of every service procedure necessary to repair them. The service-bay processor is an IBM PC/AT with a touch-control video screen and a printer. The processor hooks up to the vehicle's *assembly line communication link* (ALCL), a plug with an umbilical harness that connects the on-board computer to CAMS.

In use, CAMS automatically analyzes data from the vehicle's computer, engine circuits, and sensors, and provides a printout of the results. CAMS then interprets the information and guides the technician through a test sequence to locate the cause of the problem. Guidance takes the form of step-by-step instructions that include schematics of the vehicle's wiring harness. The technician can also use the system's manual mode of operation to locate malfunctions.

CAMS backs up the technician in three other ways. First, at a touch of a menu, vehicle specifications, service manuals, and factory service bulletins can be made available. Second, information fed into CAMS by the technician is transmitted to the host computer. Engineers from design, manufacturing, and service study problem situations in order to correct design flaws and offer field repair tips. This eliminates the need for easily lost service bulletins. Third, technicians with an unusual vehicle problem can share it using the *Echo system.* The Echo system allows the technician to share the same information seen on the CAMS' screen with an engineering specialist at the technical assistance center in Flint. Consultations by phone provide immediate feedback aimed at solving the problem.

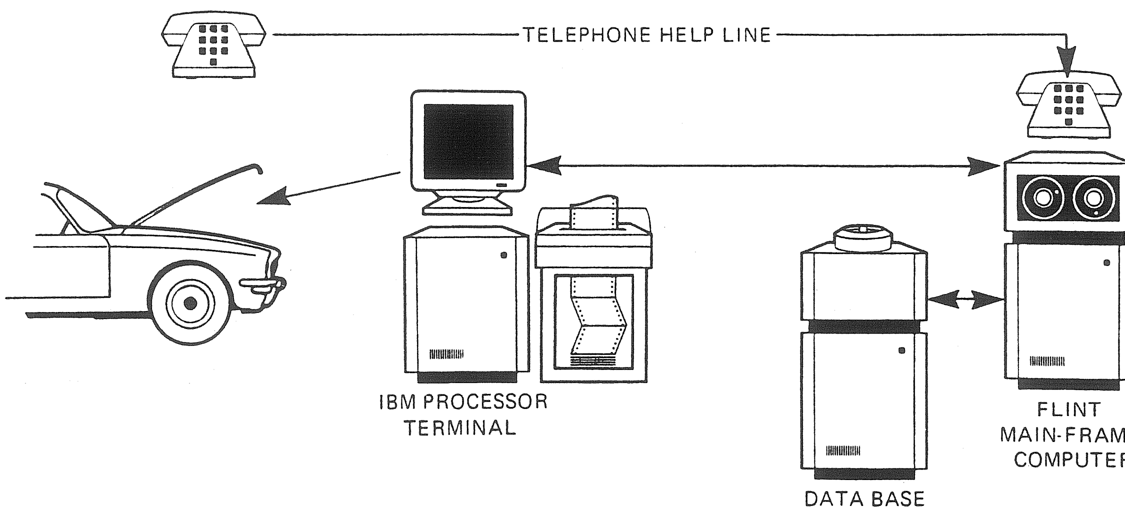


FIGURE 5-37
CAMS design and operation.

OASIS. *OASIS (On-line Automotive Service Information System)* is Ford's factory-direct communication system. OASIS is a keyboard terminal presently found in the service bays of many dealerships. The system involves a direct computer link with a mainframe computer in Dearborn, Michigan.

OASIS is primarily used for transmitting service information, such as the latest service bulletins on new techniques. To receive information, the technician identifies the vehicle and then enters a trouble code. Shortly thereafter, index numbers for applicable technical service bulletins appear on a printout. Many of these numbers are accompanied by a short abstract of the bulletin contents.

OASIS then lists possible corrective measures for the problem. The technician can then use these measures or refer to the suggested technical reference material for guidance in performing the vehicle repair.

5-8 SPECIFICATIONS, DIAGRAMS, AND DIAGNOSIS CHARTS

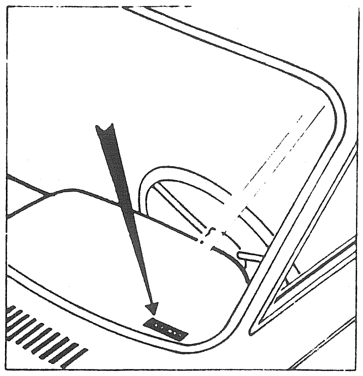
A technician will quickly find out that a substantial part of the process of repairing computerized engine control systems involves locating and following reference materials. These materials may be in the form of service manuals, service bulletins, driveability test procedures, electrical and vacuum diagrams, or quick and pinpoint test guides. In any case, in order to find and use data from these publications, the technician must be able to correctly identify the vehicle, engine, and emission control package. This is accomplished through the use of VIN numbers, and engine and emission control decals.

VIN Numbers

All cars and light trucks built since 1968 have a *vehicle identification number* (*VIN*) visible through the windshield on the driver's side (Fig. 5-38). The VIN is considered to be a combination model, part, and serial number for a specific vehicle. It is the starting point for accurate vehicle identification for any service or repair job. Most VIN plates are on the left side of the instrument panel, inside the base of the windshield.

Vehicle identification numbers adhere to a form standardized by S.A.E. For 1968-1980 vehicles, the VIN standard permits up to 15 digits of data. However, most vehicle manufacturers use 11 to 13 letters or numbers. The first 5 to 8 letters or numbers indicate the car line, the series, the body type, the engine type, the model year, and the manufacturer's assembly plant. The last 6 digits represent the serial number of a vehicle that was built in a specified assembly plant. S.A.E. expanded the VIN to 17 digits for the 1981 model year to include codes for the company, country of origin, and restraint system, and a check digit that prevents altering the VIN (see Fig. 5-38).

V.I.N. PLATE LOCATION:



MODEL YEAR OF VEHICLE:
1987 – MODEL YEAR IS H.
1986 – MODEL YEAR IS G.
1985 – MODEL YEAR IS F.
1984 – MODEL YEAR IS E.
1983 – MODEL YEAR IS D.
1982 – MODEL YEAR IS C.
1981 – MODEL YEAR IS B.
1980 – MODEL YEAR IS A.
1979 – MODEL YEAR IS 9.
1978 – MODEL YEAR IS 8.

MODEL YEAR AND ENGINE IDENTIFICATION:

1987-81

1FABP05F9HY1000001

2 ENGINE CODE (8TH CHARACTER) 1 MODEL YEAR (10TH CHARACTER)

1980-78

AB49F500001

1 MODEL YEAR (1ST CHARACTER) 2 ENGINE CODE (5TH CHARACTER)

FIGURE 5-38
Typical VIN numbers.

Manufacturers are free to use different letters or numbers in various positions on the VIN plate for various items. About the only thing that is uniform is the last six digits that represent the assembly sequence number. This arrangement makes it impossible to memorize any of the letter and number code combinations used by the manufacturers. However, there is no need for this because reference manuals will indicate which digit to check whenever there is a need to determine specific information about a vehicle for the purpose of ordering parts or locating specifications or procedures.

Engine Decals

Some manufacturers, particularly Ford, install a decal on the engine (Fig. 5-39). This decal contains an

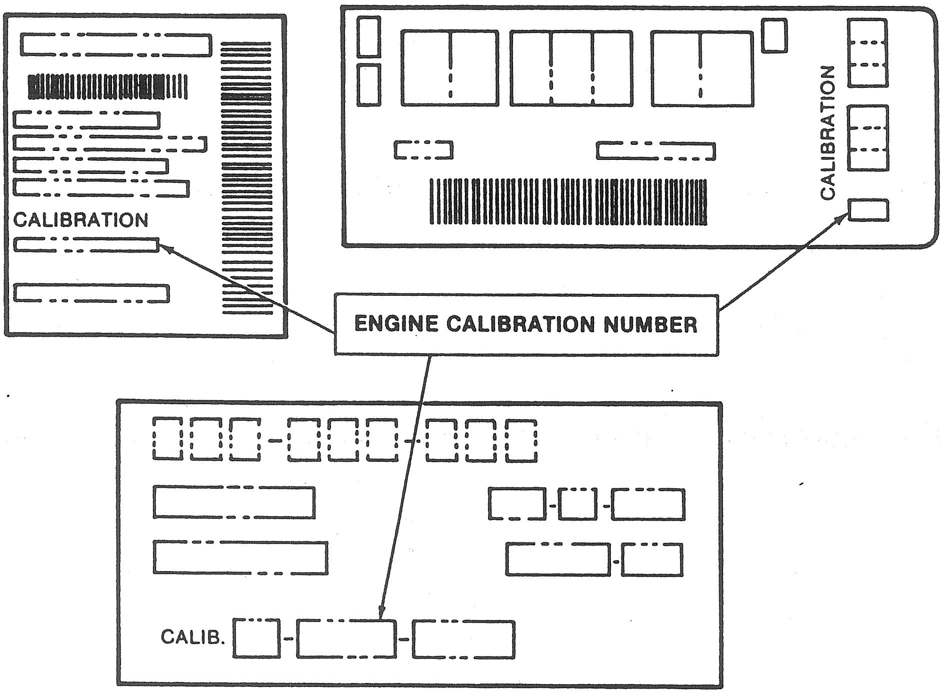


FIGURE 5–39
Engine label. (Courtesy of Ford Motor Co.)

engine code and data specifying its displacement, when and where it was built, its sequence number, and most importantly, its calibration code. The calibration code identifies what ignition system is used on the engine and the layout of its vacuum system, both of which can vary when the same power plant is used for a number of model years and vehicle configurations. Additional information on calibration codes can be found in Chapter 7, section 7-1.

Emission Decals

Now that you are aware of the importance and location of the various identification numbers and codes, let's examine some reference source materials supplied to a technician. These include emission decals, vacuum diagrams, electrical diagrams, and test guides. Federal law requires requires each automobile manufacturer to install an *emission control decal* in the engine compartment of every vehicle (Fig. 5-40). This decal gives the engine size and lists a few of the basic tune-up specifications and instructions along with some of the emission control devices used on the vehicle. The specifications may include the initial ignition timing, the curb idle speed, the enriched rpm, the fast idle speed, the exhaust emission limits, the spark plug type and gap, and the engine calibration code (for Ford vehicles).

Because manufacturers often change engine calibrations or introduce new engine/vehicle configurations in the middle of the year, information in the service manual is not always up to date. Therefore,

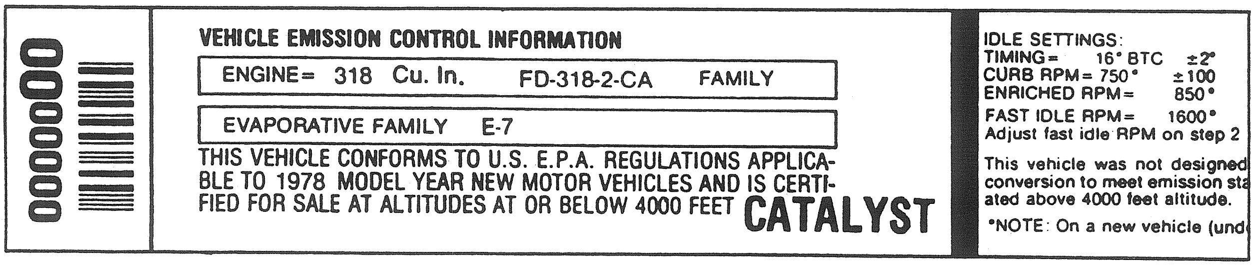


FIGURE 5–40
Typical emission control decal. (Courtesy of Chrysler Motors Corp.)

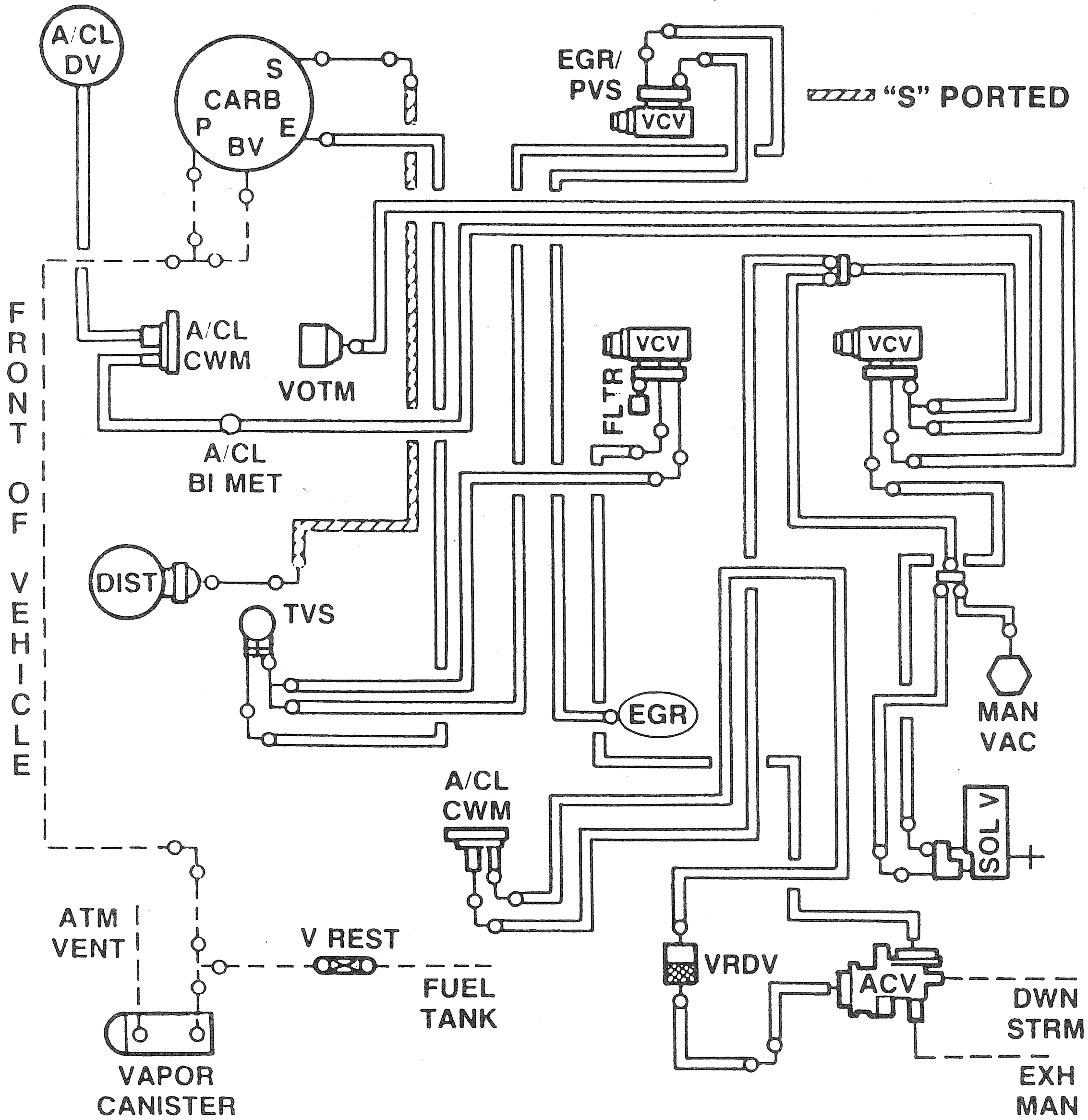


FIGURE 5–41
Typical vacuum diagram. (Courtesy of Ford Motor Co.)

if the data on an emission control decal conflict with that within the manual, follow the instructions on the decal.

Vacuum Circuit Diagrams

A *vacuum diagram* is a graphic representation of the vacuum system on a vehicle (Fig. 5-41). A vacuum diagram is an essential tool for any technician servicing contemporary automobiles due to the complexity of the system. It can be used, for example, to properly reconnect hoses removed during service work or to find where a disconnected hose belongs.

The diagrams may or may not be color coded and can be found on the emission control label, in the appropriate service manual, or various aftermarket technical publications. In any case, the diagram on the emission decal will reflect any mid-year changes and should be used if it conflicts with one found in a manual.

Each diagram will illustrate the particular emission systems' vacuum sources, components, and hose routing. In most cases, the diagram does not show the hoses, lines, or components to other vacuum-operated units that are not part of the emission control system.

Notice the vacuum sources shown in Fig. 5-41. The S port on the carburetor is a ported vacuum

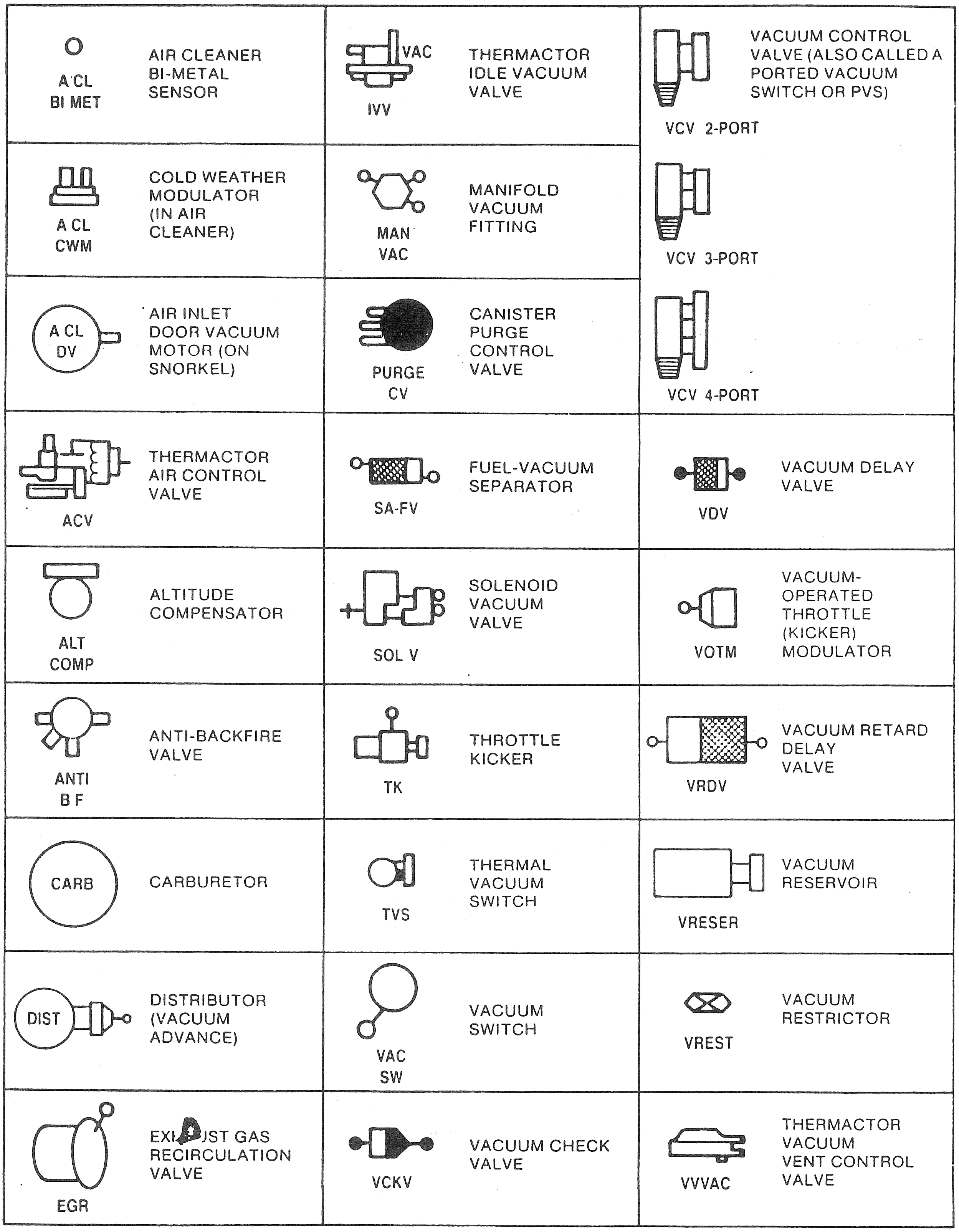


FIGURE 5–42
Vacuum diagram symbols. (Courtesy of Ford Motor Co.)

source for the distributor. The E port on the carburetor provides the vacuum signal to the exhaust gas recirculation (EGR) valve. The P port on the carburetor provides a ported vacuum source to purge the vapor canister. The manifold vacuum port supplies the vacuum to operate the remaining pneumatic components of the system.

In many cases, the components of the system are shown by symbols (Fig. 5-42). The symbols are again graphic representations of a particular part, and they may vary somewhat among manufacturers. The ones shown in the example are also identified by symbol code letters such as A/CL BI MET for air cleaner bimetal sensor.

To illustrate the use of a diagram, follow the hose routing for the EGR system shown in Fig. 5-41. The first hose connects the EGR valve itself and the EGR/Ported Vacuum Switch. From it, a second hose runs to the Thermostatic Vacuum Switch. Finally, a third hose connects the TVS to the E port on the carburetor. The hoses mentioned may be single or formed into a vacuum harness consisting of a number of hoses attached to some form of connector or fitting.

Electrical Wiring Diagrams

An *electrical wiring diagram* like its vacuum counterpart is a graphic representation. But in the case of a wiring diagram, it can illustrate all or just a small portion of a vehicle's electrical system (Fig. 5-43).

Years ago, before the electrical system of the automobile became so complex, it was common to see one diagram or maybe two for the whole vehicle. However, this is not the situation now. Today, in vehicle service manuals and aftermarket technical books, diagrams are provided for particular sections, systems, and even individual components found on the vehicle. Moreover, these diagrams may be situated in a number of locations throughout a given reference book. However, the manual index, or in some cases a step in a given troubleshooting procedure, will advise you of which diagram to use.

As mentioned in Chapter 2, a wiring diagram contains a number of symbols. The symbols may be standard ones used throughout the industry or especially developed by a particular manufacturer. In any case, you must become familiar with the symbols before attempting to use a circuit diagram.

When using the electrical diagram, look at it as a road map, with the power source as the starting point. The wiring represents the different roads or paths to follow until you reach your destination, that is, the component that is malfunctioning. Of course, the main power source is the vehicle battery. But in a typical electrical circuit, the source may be a switch, fuse panel, or even a microcomputer, because they all receive power from the battery. The darkened blocks in Fig. 5-43 show the power sources in this particular circuit diagram.

In diagnosing a certain problem in a circuit, the first step is to determine if there is power at the source when there should be. If there is, the next logical move would be to determine via a voltmeter or test light if power exists at the component that is malfunctioning. Power to a component indicates continuity in the circuit. In this case, the component is probably defective or there is a grounding problem.

If the component is not receiving power, you will have to backtrack along the wiring until you locate the break. This again is best accomplished through the use of a voltmeter or test light.

Caution: *Make sure you always use the testing device recommended by the manufacturer when tracing for an opening in a circuit. In microcomputer systems, it is very possible to damage an electronic circuit if the wrong tool is used.*

Driveability Test Procedures

When attempting to locate the cause of either a no-start condition or a driveability problem, it is mandatory that you use a *driveability test procedure, quick,* or *pinpoint test guide.* A procedure or test guide provides a systematic, step-by-step method of checking the function of each engine control system to determine if it is operating as designed. Moreover, if a particular system or component is found to be malfunctioning, the procedure set forth will guide you to where the problem is or instruct you to proceed using a completely different test sequence.

All manufacturers provide guides or procedures for their vehicles. They are normally found in the vehicle service manual or in a special driveability test procedure booklet. In either case, do not attempt to troubleshoot an engine control system without following a guide, and never skip any of the specified steps. Improper diagnosis can cause damage to the microcomputer or system components or lead to the replacement of nonfaulty parts.

Figure 5-44 illustrates a typical driveability test procedure. Notice that this is Test 3, designed to check battery-sensing circuit voltage when a ser-

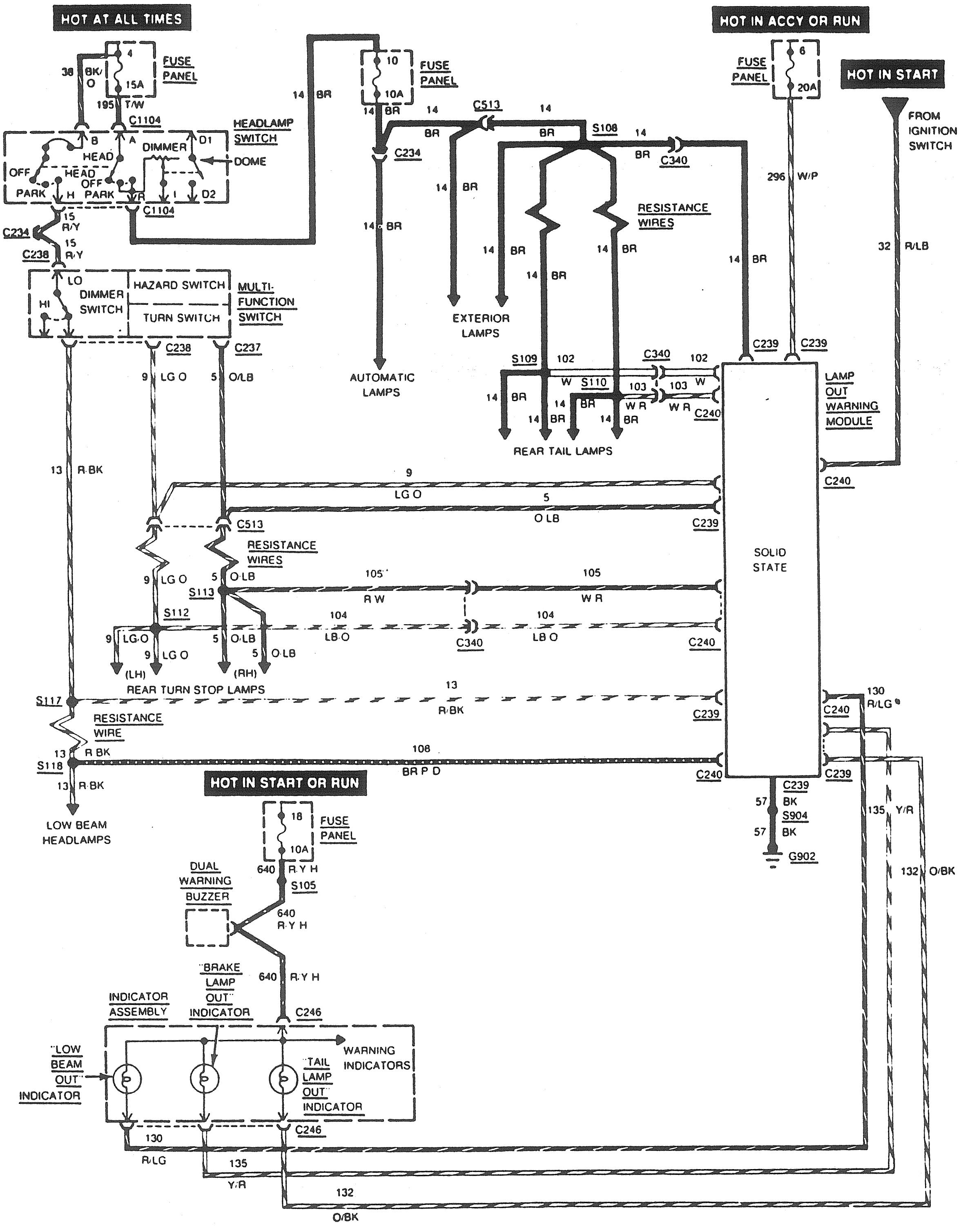


FIGURE 5–43
Typical electrical diagram. (Courtesy of Ford Motor Co.)

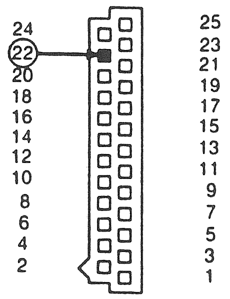
<table>
<tr><th>TEST 3</th><th>STEP A</th><th colspan="2">CHECKING BATTERY SENSING CIRCUIT (CODE 16)</th></tr>
<tr><th colspan="2">PROCEDURE</th><th>TEST INDICATION</th><th>ACTION REQUIRED</th></tr>
<tr><td rowspan="2">• Turn the ignition switch off.
• Disconnect the black connector from the logic module.
• Connect a voltmeter to cavity No. 22 of the logic module black connector and ground.</td><td rowspan="2">LOGIC MODULE
BLACK CONNECTOR
VIEW FROM WIRE END</td><td rowspan="2">• Voltmeter should read within one volt of battery voltage.</td><td>• Voltage okay, replacing the logic module.
CAUTION: Before replacing the logic module, make sure the terminal in cavity No. 22 is not crushed so that it cannot touch the logic module pin.</td></tr>
<tr><td>• 0 volts, repair the wire of cavity No. 22 for an open circuit to the wiring harness splice.</td></tr>
</table>

FIGURE 5-44
Driveability test procedure. (Courtesy of Chrysler Motors Corp.)

vice Code 16 is stored in microcomputer memory. The left two columns of the procedure provide the step-by-step test sequence and an illustration to assist in pinpointing cavity No. 22. The right two columns provide test indications and show what the technician should do if voltage is or is not okay.

Quick and Pinpoint Test Guides

Let's now look at another method of testing for malfunctions that is used by Ford Motor Company. It involves the use of two test guides, the quick and pinpoint. A *quick test* (Fig. 5-45) is a functional test of the system to detect hard fault codes. A *hard fault code* is caused by a problem that is continuous, not intermittent.

The quick test guide basically tells a technician how to obtain trouble codes, but it does not describe any procedure for diagnosing problems other than those requiring just a part replacement. Instead, it provides test results in the left column and informs the technician which pinpoint test to use. For example, if a Code 21 is stored in memory, the quick test refers the technician to Pinpoint Test Step DE1.

A *pinpoint test guide* (Fig. 5-46), on the other hand, describes how to locate the cause of the code. Each pinpoint test guide has three columns of information. The left column provides the step-by-step procedure, the center provides the test results, and the right indicates the action to take.

5-9 GENERAL SAFETY PRECAUTIONS

As you read through this text, you will come across some italicized material entitled notes and cautions. Each of these has a specific purpose. *Notes* provide added information to help you either understand the design and operation of a system or component or complete a particular procedure. *Cautions* are warnings given to prevent errors that could cause personal injury or damage to the vehicle.

3.1	KEY ON, ENGINE OFF SELF-TEST

- Using the On Demand Service Codes from Key On, Engine Off Quick Test Step [3.0] follow the instructions in the Action To Take column in this Step.
- When more than one service code is received, always start service with the first code received.
- Whenever a repair is made, REPEAT Quick Test.

NOTE: **Before proceeding to the specified Pinpoint Test, read the instructions on how to use the Pinpoint Tests at the beginning of the Pinpoint Test section.**

RESULT		ACTION TO TAKE
ON DEMAND SERVICE CODES 15	▶	REPLACE processor. REPEAT Quick Test.
21	▶	GO to Pinpoint Test Step [DE1].
22	▶	GO to Pinpoint Test Step [DF4].
23	▶	GO to Pinpoint Test Step [DH1].
24	▶	GO to Pinpoint Test Step [DB1].
31	▶	GO to Pinpoint Test Step [DL40].
51	▶	GO to Pinpoint Test Step [DE10].
53	▶	GO to Pinpoint Test Step [DH20].
54	▶	GO to Pinpoint Test Step [DB10].
61	▶	GO to Pinpoint Test Step [DE20].
63	▶	GO to Pinpoint Test Step [DH30].
64	▶	GO to Pinpoint Test Step [DB20].
81	▶	GO to Pinpoint Test Step [UA1].
82	▶	GO to Pinpoint Test Step [UA1].

FIGURE 5-45
Quick test. (Courtesy of Ford Motor Co.)

TEST STEP		RESULT	ACTION TO TAKE
DE1	SERVICE CODE 21: CHECK ENGINE OPERATING TEMPERATURE		
• Run engine for 2 minutes at 2,000 rpm. • Check that upper radiator hose is hot and pressurized. • Rerun Quick Test.		Vehicle stalls ▶	Do not service code 21 at this time. REFER to diagnosis by symptoms.
		Code 21 present ▶	GO to DE2.
		Code 21 not present ▶	SERVICE other codes as necessary.

FIGURE 5-46
Pinpoint test. (Courtesy of Ford Motor Co.).

Although certain procedures require specific precautions, there are also many general safety practices that you must follow. These practices are summarized below.

1. Most technicians are not aware of the need to protect microcomputer systems against damage from static electricity. Static charges of as low as 30 volts can destroy expensive electronic circuitry. Voltages much higher than this are carried on the surface of humans without their knowing it is there. The best method of preventing microcomputer damage is to drain the charge and provide a static-free work area. This can be accomplished easily by using 3M's static protection kit. This kit includes two different-sized wrist bands, a flexible static-dissipating work surface mat, and a ground cord that connects the wrist band and mat together while grounding them to the vehicle frame.

2. Always wear safety glasses in any area or for any job where an eye hazard exists.

3. When working under a raised vehicle, always install safety stands.

4. Make sure the ignition switch is always in the off position unless otherwise required by a given procedure.

5. Flammable liquids and combustible materials are always present in an automotive repair facility. You can minimize fire hazards by not smoking in a shop area.

6. Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.

7. To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, muffler, catalytic converter, and tailpipe.

8. To avoid injury, always remove watches, rings, loose hanging jewelry, and loose clothing before beginning work on a vehicle.

9. Keep your hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in underhood temperatures, even though the ignition switch is in the off position. Therefore, care must be taken to ensure that the fan motor is completely disconnected when working under the hood.

10. Set the parking brake when working on a vehicle. Also, if the vehicle has an automatic transmission, set it in park. Finally, place 4-by-4-inch or larger wood blocks at the front and rear surfaces of at least two tires to provide further restraint against inadvertent vehicle movement.

11. Keep yourself and your clothing away from moving parts, especially the fan and belts, when the engine is operating.

12. Never start an engine when someone is under the vehicle or leaning into the engine compartment. Also, do not start an engine with tools or parts lying on the air cleaner.

13. Never choke an engine with your hand over the carburetor.

14. Never pour gasoline into a carburetor when starting an engine or when an engine is operating.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-TEST

1. What is a static protection kit and why is it needed [5-9]?
2. Describe the basic difference between analog and digital meters [5-1].
3. Why are vehicle identification numbers and calibration codes important [5-8]?
4. Describe the four uses of a voltmeter [5-2].
5. Describe how aftermarket scanners are programmed to fit any microcomputer system [5-7].
6. Where is the location and what is the function of the ammeter shunt resistor [5-3]?
7. Describe what occurs to microcomputer operation if engine performance is poor [5-6].
8. What is the basic design difference between an analog ohmmeter and either a voltmeter or ammeter [5-4]?
9. How does the 12-volt test light and the self-powered test light differ [5-5]?

REVIEW

1. What procedure should be used to prevent a vehicle from accidentally moving in the shop [5-9]?
   a. set the parking brake.
   b. Place the transmission in park.
   c. Block the wheels.
   d. Do all the above.
2. Which meter type has the D'Arsonval movement [5-1]?
   a. digital voltmeter
   b. analog voltmeter
   c. digital ohmmeter
   d. none of these
3. When diagnosing a microcomputer system malfunction, the technician must follow [5-8]
   a. a driveability test procedure.
   b. quick and pinpoint tests.
   c. both a and b.
   d. neither a nor b.
4. Which type of test instrument is the most accurate [5-1]?
   a. digital
   b. analog
   c. test light
   d. test lead
5. When attempting to trace an electrical circuit problem on a diagram, always begin at the [5-8]
   a. malfunctioning load device.
   b. power source.
   c. starter motor.
   d. alternator.
6. How are the leads of a voltmeter connected into a circuit to read its available voltage?
   a. across the circuit
   b. so the meter parallels the existing circuit
   c. both a and b
   d. neither a nor b
7. Every new automobile must have what type of decal [5-8]?
   a. emissions decal
   b. engine decal
   c. fuel economy decal
   d. load decal
8. What causes voltage drop in a circuit [5-2]?
   a. current flow through a resistance unit
   b. a charging system malfunction
   c. a malfunctioning battery
   d. a faulty starter
9. The STAR tester is used on which Ford system [5-7]?
   a. MCU
   b. EEC-II
   c. EEC-IV
   d. both a and c
10. How is the ammeter connected into a circuit [5-3]?
    a. in series
    b. in parallel
    c. in series-parallel
    d. none of these

11. Which type of gas analyzer will function on any vehicle [5-6]?
    a. two-gas
    b. four-gas
    c. both a and b
    d. neither a nor b

12. An ohmmeter that can be used to test microcomputer circuits must have [5-4]
    a. high internal resistance.
    b. low internal resistance.
    c. an external power source.
    d. no power source.

13. Which ignition pattern is most commonly read on a scope [5-6]?
    a. secondary
    b. primary
    c. both a and b
    d. neither a nor b

14. What must be done before using an analog ohmmeter to test the resistance of a part [5-4]?
    a. The unit must be disconnected from the circuit.
    b. The ohmmeter must be calibrated.
    c. both a and b
    d. neither a nor b

15. Which test instrument can be used to check service codes stored in microcomputer memory [5-6]?
    a. analog voltmeter
    b. dwell meter
    c. automatic readout box or scanner
    d. all of these

16. What does an infinity reading on an ohmmeter mean [5-4]?
    a. There is so much resistance it cannot be read on the scale.
    b. There is so little resistance it cannot be read on the scale.
    c. There is power to the component being tested.
    d. none of these

17. What is the function of a power timing light [5-6]?
    a. to check initial timing
    b. to measure the amount of total timing advancement
    c. both a and b
    d. neither a nor b

18. How can a 12-volt test light be connected to a circuit ground [5-5]?
    a. with its alligator clip
    b. by its probe tip
    c. both a and b
    d. neither a nor b

19. What test instrument checks the piston's ability to create a low-pressure area [5-6]?
    a. compression tester
    b. vacuum gauge
    c. vacuum pump
    d. both b and c

20. How is a jumper lead used as a diagnotic tool [5-5]?
    a. to bypass a portion of a circuit
    b. to bypass a circuit load device
    c. to remove the resistance from a powered circuit
    d. none of these

Chapter 6

FORD ELECTRONIC IGNITION SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to:

- explain the negative characteristics associated with standard ignition systems.
- describe the basic design and operation of the Ford transistorized ignition system.
- describe the design of Ford's solid state ignition system.
- identify and know the function of the components of a Duraspark I ignition system.
- describe the design of a Duraspark II ignition system.
- identify and know the function of the components of a Duraspark III ignition system.
- describe the basic design and operation of magnetic-pulse and Hall-effect trigger circuits.
- identify and know the function of the parts of a thick-film integrated (TFI) ignition system.

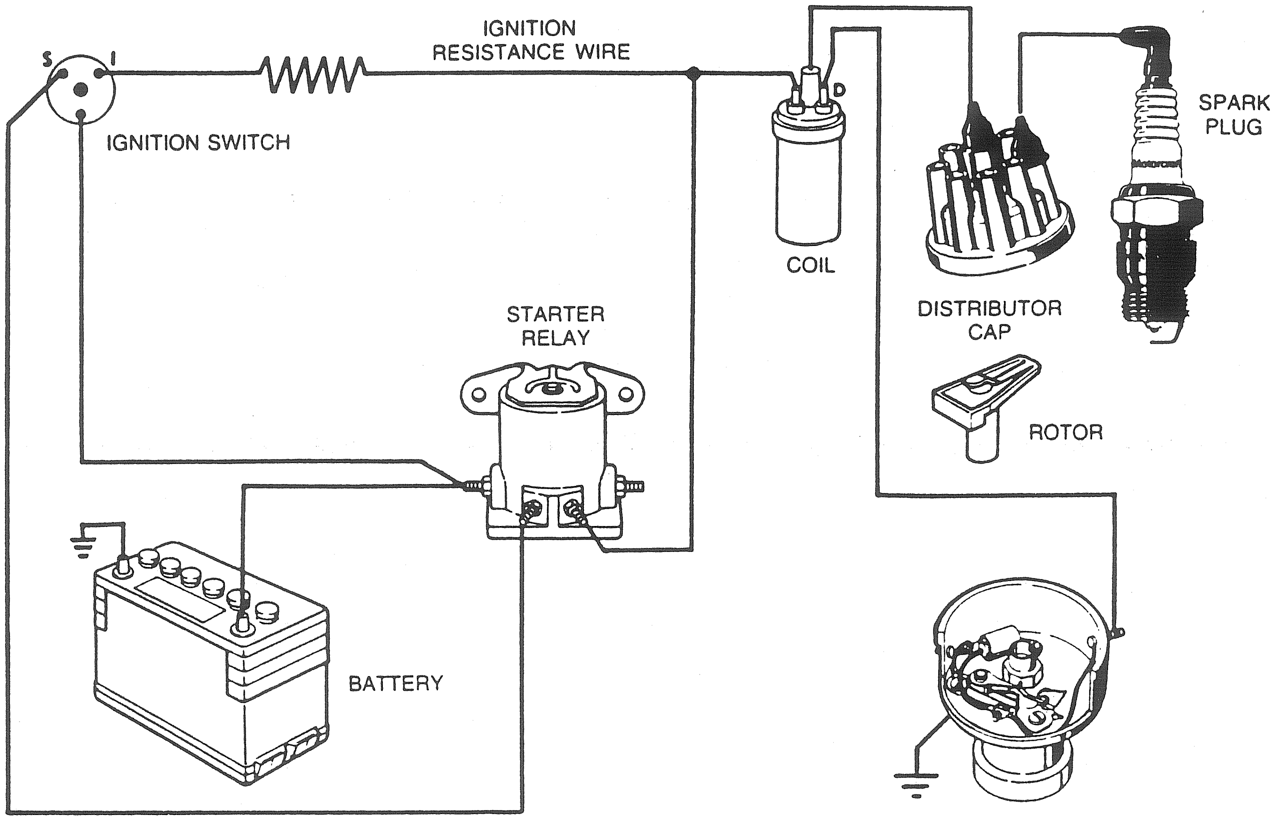


FIGURE 6–1
Standard contact point ignition system. (Courtesy of Ford Motor Co.)

Although the standard contact point ignition system has served the automotive industry well since 1912, it no longer appears on contemporary automobiles. In its place, Ford and the other vehicle manufacturers are using some form of electronic ignition system. The underlying reason for this changeover was the imposition of federal emission standards beginning in the late 1960s. These standards mandated the effective control of nitrogen oxides (NO_x), hydrocarbons (HC), and carbon monoxide (CO).

As the years went by, the standards became more strict. This forced manufacturers to install various emission control systems and to lean out air/fuel mixtures during certain phases of engine operation. However, the engine still had to deliver sufficient power to meet driveability requirements.

It was not long before engineers found that the old standard system could no longer meet ignition requirements. The answer was an electronic ignition system that would respond faster and provide spark plug firing with a precision and intensity that never existed before. To fully understand why electronic systems are far more efficient, let's review some of the negative characteristics associated with standard ignition.

6-1 NEGATIVE CHARACTERISTICS OF STANDARD IGNITION SYSTEMS

The breaker point ignition system (Fig. 6–1) has four inherent negative qualities that curtail its continued use on emission-controlled engines. These include (1) insufficient output voltage, (2) a tendency for voltage decay at high engine speed, (3) an increased maintenance requirement, and (4) a fixed amount of built-in timing advance. Although some of these problems can overlap, each will be discussed separately for purposes of clarification.

Insufficient Available Output Voltage

It is a well-known fact that nonemission-controlled engines require less ignition coil output voltage at idle to create an arc across the plug electrodes. There is a good reason for this. The spark plugs on these engines only require a gap of about 0.035 inch (0.88 mm) because the relatively rich air/fuel mixture at idle creates a rather good current-carrying conductor. As a result, operating voltages at idle are lower. Of course, the available output voltage of the system had to be much higher than this to meet ignition

demands during high engine loads and speeds.

Enter the emission-controlled engine with its leaned out air/fuel mixture at idle. This mixture contained fewer conductive gasoline particles. Consequently, many manufacturers increased spark plug gaps to accommodate a larger quantity of fuel.

The larger gap has the effect of increasing the required system voltage necessary to initiate the arc between the spark plug electrodes. With a higher voltage requirement at idle, the available system voltage must also be increased or voltage reserve will be too small. *Voltage reserve* is the difference between required voltage and available voltage. If voltage reserve is too small, the spark plugs will begin to misfire under heavy engine loading and high speeds. This produces higher emission levels and reduces fuel economy.

Voltage Decay at High Engine Speeds

Voltage decay is a reduction in available system voltage at high engine speeds. To understand this concept, let's review the term dwell as it relates to breaker points and coil operation. *Dwell* is the number of degrees of distributor shaft rotation in which the contact points of a standard system remain closed (Fig. 6-2). Dwell is very important because during this period, current flow from the battery through the primary side of the coil must produce a strong electromagnetic field around the primary and secondary coil windings. When this field reaches its full magnetic strength, it is called *magnetic saturation.*

However, magnetic saturation does not occur instantaneously due to *self-induction,* which is the induction of a counter voltage into the coil windings as current passes through them. The reason for this occurrence is that as current passes through each winding, it creates a magnetic field consisting of expanding concentric circles that move outward from the wire. These magnetic circles cut across a section of an adjacent winding before the current can reach that point. The magnetic circles induce a *counter voltage* in the winding, or one tending to cause current flow in an opposite direction to that from the battery (Fig. 6-3). This action resists the flow of current through the entire coil that produces the magnetic field.

Actually, the current cannot flow that way because the battery is already forcing electrons through every turn of the windings in the opposite direction (Fig. 6-4). However, there is this tendency for induced current flow in a reverse direction by the magnetic field as it builds up. As a result, it is harder for the electrons from the battery to move through the primary coil windings. The magnetic field of every winding produces this tendency on an adjacent coil turn, thereby resisting the passage of additional current through the entire unit.

Thus, a period of time is necessary for the battery to overcome this effect and increase the amount of current to the maximum, as determined by the

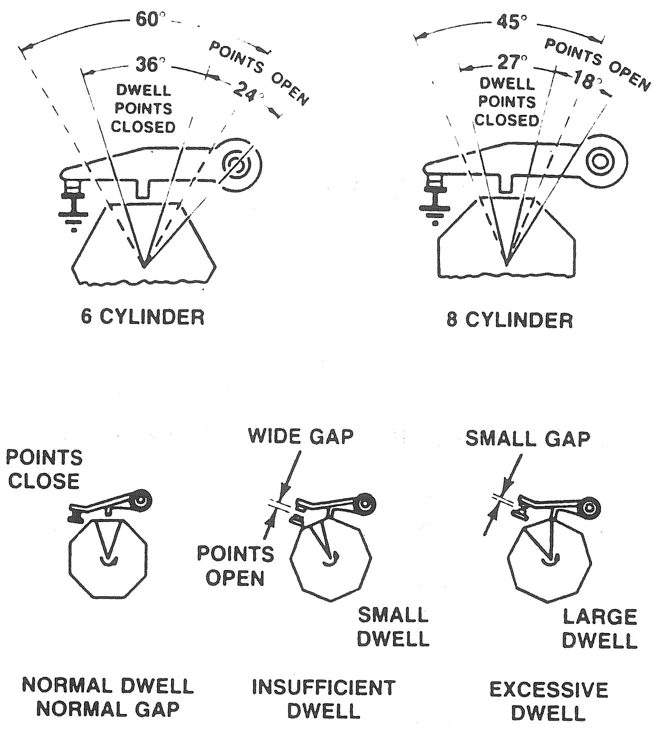


FIGURE 6-2
Dwell is the number of degrees the distributor shaft turns with the points closed. (Courtesy of Ford Motor Co.)

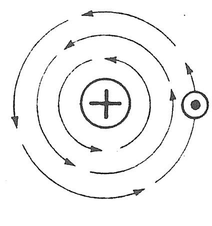


FIGURE 6-3
Effect of the magnetic field from one winding on an adjacent winding. The plus mark indicates the direction of current flow from the battery. The dot shows the direction of current flow due to the induction of a counter voltage.

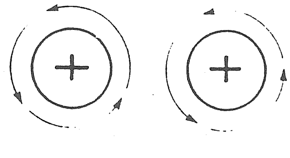


FIGURE 6-4
Battery forces the current to flow through all the windings in one direction.

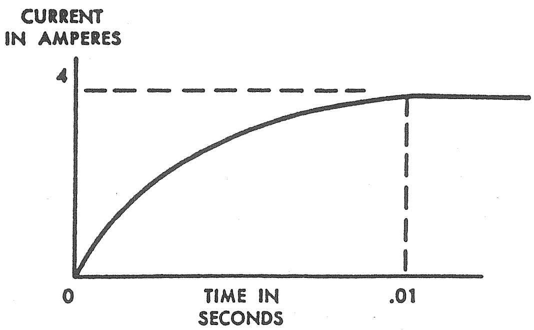


FIGURE 6-5
Graph of the coil build-up time and current flow.

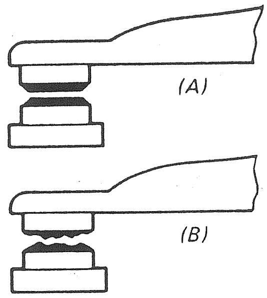


FIGURE 6-6
(A) Normal point-open condition. (B) Badly eroded and pitted points.

total resistance in the primary coil circuit. This interval is commonly referred to as the *dwell period* or *build-up time* and is only a fraction of a second (Fig. 6-5). In this illustration, a time lag of 0.01 second occurs before the current value reaches four amperes with the contact points closed. This exceedingly short time period makes the situation appear unimportant, but it has always created problems for engineers who design ignition systems.

During idle and low engine speeds, the dwell period is of long enough duration for the primary coil to produce the strong field, resulting in a more than adequate available secondary coil voltage as the points open. At higher engine speeds, a different situation exists. Although point dwell remains constant, there is less time for the primary coil build-up. In other words, the points open and close much faster at high speeds, but their closed period, in degrees, remains the same. As a result, there is a reduction in the strength of the magnetic field produced by the primary coil, which reduces available output voltage, or decay. Coil reserve is therefore lower, increasing the tendency for spark plug misfires.

However, with electronic controls replacing the use of contact points, the dwell period can be lengthened as necessary. This, of course, provides a more constant coil output even at high engine speeds.

Increased Maintenance Requirement

The standard contact point ignition system does require frequent inspection and service or it will begin to malfunction. Although the spark plugs normally need attention at given intervals, they tend to become fouled more easily due to problems with the contact points. The main part of the system that has to be checked most often and that usually wears out the fastest is the contact point assembly.

There are a number of reasons for this. First, since the contact points open mechanically by means of a rubbing block riding on the distributor cam, there is opportunity for wear. As the rubbing block wears down, the dwell period increases (see Fig. 6-2). Increased dwell would seem to increase the efficiency of the system, but this is not the case. The lengthened dwell period over the specified amount has the effect of retarding ignition timing and causing increased point arc. The retarded timing is the result of the points opening later than they should. The excessive point arc is due to the increased magnetic field created by a lengthed dwell period. When the points open in this situation, the self-induced voltage in the primary windings is higher than it should be. Therefore, the condenser cannot absorb the higher voltage level, resulting in arcing at the points.

Second, because the contact points are an electrical switch, they are subjected to arcing during both opening and closing periods. This tends to erode away the point surfaces. The points arc slightly as they close due to the one ampere to four amperes of battery current passing through the contacts on the way to the coil.

As the points open, the magnetic field around the primary coil collapses. This not only induces 30,000 volts to about 50,000 volts in the secondary coil due to mutual induction, but generates 250 volts to 450 volts in the primary coil due to a form of self-induction. This latter voltage has a polarity that attempts to keep current flowing across the opening points.

The condenser is in the primary circuit to temporarily absorb this primary voltage so the points can open without arcing and the magnetic field around the primary coil can collapse quickly. The problem here is that there is no single condenser capacity that is right for all phases of ignition system operation. Consequently, arcing of the points is a

constant problem that eventually leads to complete deterioration of the point material (Fig. 6-6).

As the surfaces burn away, the dwell period decreases because the contact points stay open longer. This action advances the ignition timing and causes voltage decay at high engine speeds. Therefore, the spark plugs begin to misfire and foul.

The third maintenance problem with contact points deals with their alignment, spring tension, and adjustment. After installation, the contact point surfaces must be parallel, and at least 90 percent of the surface area should mate with the points closed. If not, the points fail prematurely due to arcing.

If spring tension is too weak after installation, the points will bounce. *Point bounce* is a condition in which the points pop back open after closing, and it usually occurs at higher engine speeds. The end result is high-speed spark plug misfire.

If spring tension is too great, the rubbing block, cam lobe, and distributor shaft bushings will wear out prematurely. This causes the timing dwell to vary not only over a period of time but also from cylinder to cylinder.

There are two methods of adjusting contact points. The first requires the use of a dwell meter and is the most accurate method. The second and most common adjustment precedure is to measure the space between the open points with a feeler gauge (Fig. 6-7). However, this method is not too reliable for several reasons. First, the technician has to be sure the rubbing block is centered on the high point of the cam at the beginning of the procedure, which is not always an easy thing to do. Second, each technician's feel on the gauge is different, so it is easy to set the points either too close together or too far apart. In either case, the dwell period is affected as is total ignition system performance.

It should be obvious after this discussion that the best way to improve ignition system performance is to find a way to get rid of the contact points. Basically, this is one of the main differences between standard and electronic systems. The former uses contact points to control primary coil current flow; whereas, the electronic systems use a switching transistor for more reliable, maintenance-free operation.

Fixed Built-in Timing Advance

Ignition timing is a major factor in both fuel economy and driveability. It is also a critical factor in the control of harmful exhaust emissions.

As mentioned in Chapter 1, there are two fixed

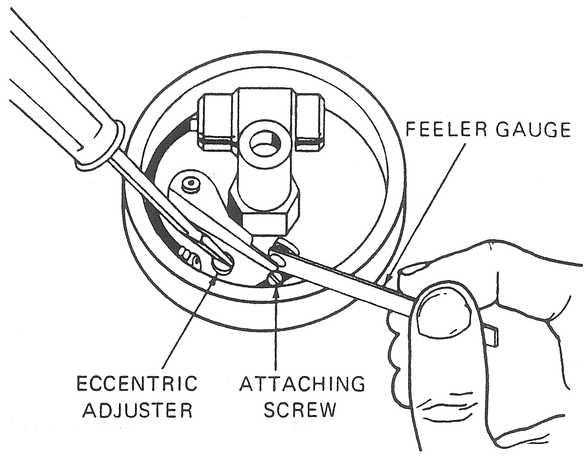


FIGURE 6-7
Adjusting contact point opening with a feeler gauge.

types of timing advance mechanisms built into the standard and many electronic ignition distributors. The mechanical advance alters ignition timing relative to engine speed. The vacuum unit advances the timing to match engine load conditions.

With both of these mechanisms, the amount of advance is fixed by the design of the unit itself. In other words, each unit can only advance the timing a given amount to correspond to certain conditions. For instance, the mass of the counterweights and spring tension determine at what engine speed and by how much the mechanism will ultimately advance the timing.

Often neither of these mechanisms can respond quickly enough to changes in engine operating conditions. The timing may be automatically advanced too much or too little during a given engine operating phase. This can cause engine hard starting, loss of power, pinging, excessive fuel consumption, increased emissions, and poor driveability.

Computer-controlled ignition timing can overcome this response problem by not being completely dependent on speed and load input signals. The computer can therefore adjust the timing to meet the greatest need during any driving condition. For instance, following a cold start, timing may be advanced to enhance driveability. During light load operation, with a partially warmed-up engine, timing can be retarded slightly to hasten engine warm-up and reduce exhaust emissions. Finally, during acceleration or wide-open throttle operation, timing may be advanced for maximum torque output.

An electronic timing system consists of a processor and a number of sensors (Fig. 6-8) that work together to determine more exactly the ignition timing needs of an engine. The sensors monitor such items as throttle position, engine vacuum, air and

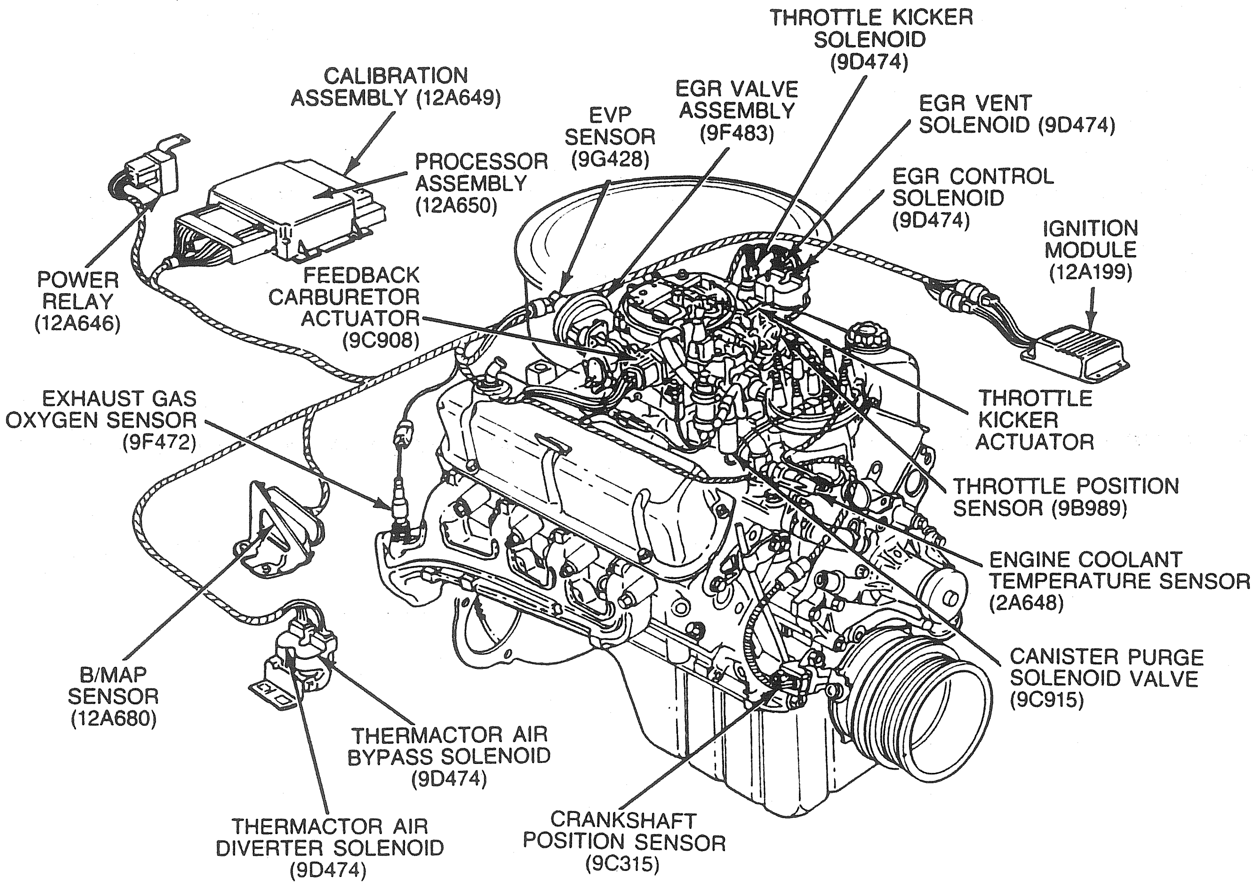


FIGURE 6–8
Typical computerized engine control system with electronic spark control. (Courtesy of Ford Motor Co.)

coolant temperatures, and engine speed. The sensors then relay this information to the computer.

The computer has integrated circuits programmed to interpret this information and calculate the proper timing for each firing cycle. Because of the extreme speed of the computer, the timing is updated many times each second.

6-2 FORD TRANSISTORIZED IGNITION SYSTEM

The Ford transistorized ignition system was offered as optional equipment on high-performance engines from 1963–1967. This system was Ford's first attempt at remedying the electrical and mechanical shortcomings of the standard contact point ignition system. The main advantages of the system are a hotter spark, more precise timing, longer point life, and a faster primary circuit switching speed than was ever possible with contact points.

A schematic of a transistor system is shown in Fig. 6–9. The contact points are attached to the transistor instead of being connected in series with the primary windings of the coil. The contact points control the operation of the transistor within the amplifier.

The switching transistor switches the primary coil current on and off. When the contact points are closed, the transistor conducts, and current flows through the primary windings and the magnetic field expands. With the points open, the transistor stops conducting current flow, and the magnetic field around the primary coil collapses. This induces a high voltage in the secondary windings and an arc at the spark plug electrodes.

The ignition coil of this system is designed to draw a peak primary current of 12 amperes. The larger current passing through the coil primary windings produces a much higher secondary voltage and a much hotter spark at the plugs, even at high engine speed.

Ordinary contact points would burn out in a short time if they carried 12 amperes of current flow.

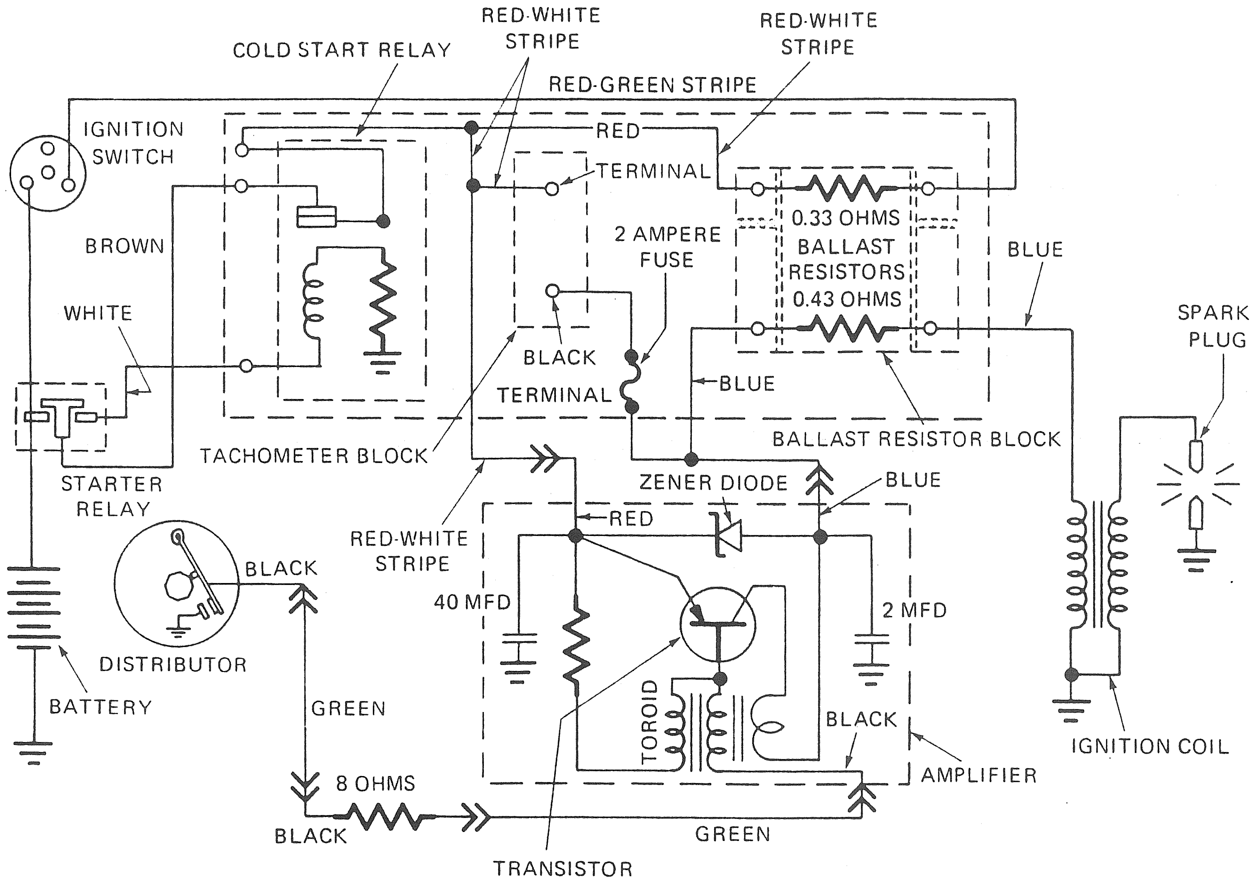


FIGURE 6–9
Schematic of a Ford transistorized ignition system.

However, the switching transistor can easily handle this current. The points in this system are only required to handle about 0.5 ampere to control the switching transistor; this lower current flow means longer point life. In fact, with such a small amount of current, pitting of the contact point surfaces is eliminated, and point life is extended to 40,000 miles (64.374 km) or more as long as the rubbing block does not wear out.

There is no condenser installed in the distributor. Instead, it is incorporated into the amplifier assembly. In addition, the capacity of the condenser is 2 microfarads; the capacity of the condenser in a standard system is about 0.25 microfarad.

This system also utilizes a ballast-resistor relay assembly that is enclosed in a fiber cover. This unit mounts in the engine compartment of a vehicle and contains a dual ceramic ballast resistor, a tachometer connector block, and a cold-start relay.

The tachometer connector block is necessary to attach a dwell meter or tachometer into the system. *These instruments must not be connected to the system by any other means, or inaccurate readings or damage to the circuit may result.* Note the two-ampere fuse in the lead to the tachometer block. It helps protect the transistor from improper use of test equipment.

During starting, the cold-start relay bypasses the 0.33-ohm resistor if battery voltage drops below 10.5 volts. In this situation, full available voltage is then applied to the system to ensure a sufficient spark at the plugs for starting the engine.

6-3 FORD SOLID STATE IGNITION SYSTEM

In 1973, Ford Motor Company installed its first solid state ignition on some Mark IV models. In 1974 the system became optional equipment on the LTD models and some medium trucks. By 1975, it became standard equipment on all passenger vehicles and medium trucks under 10,000 pounds of gross vehicle weight (GVW).

The solid state ignition system is designed to

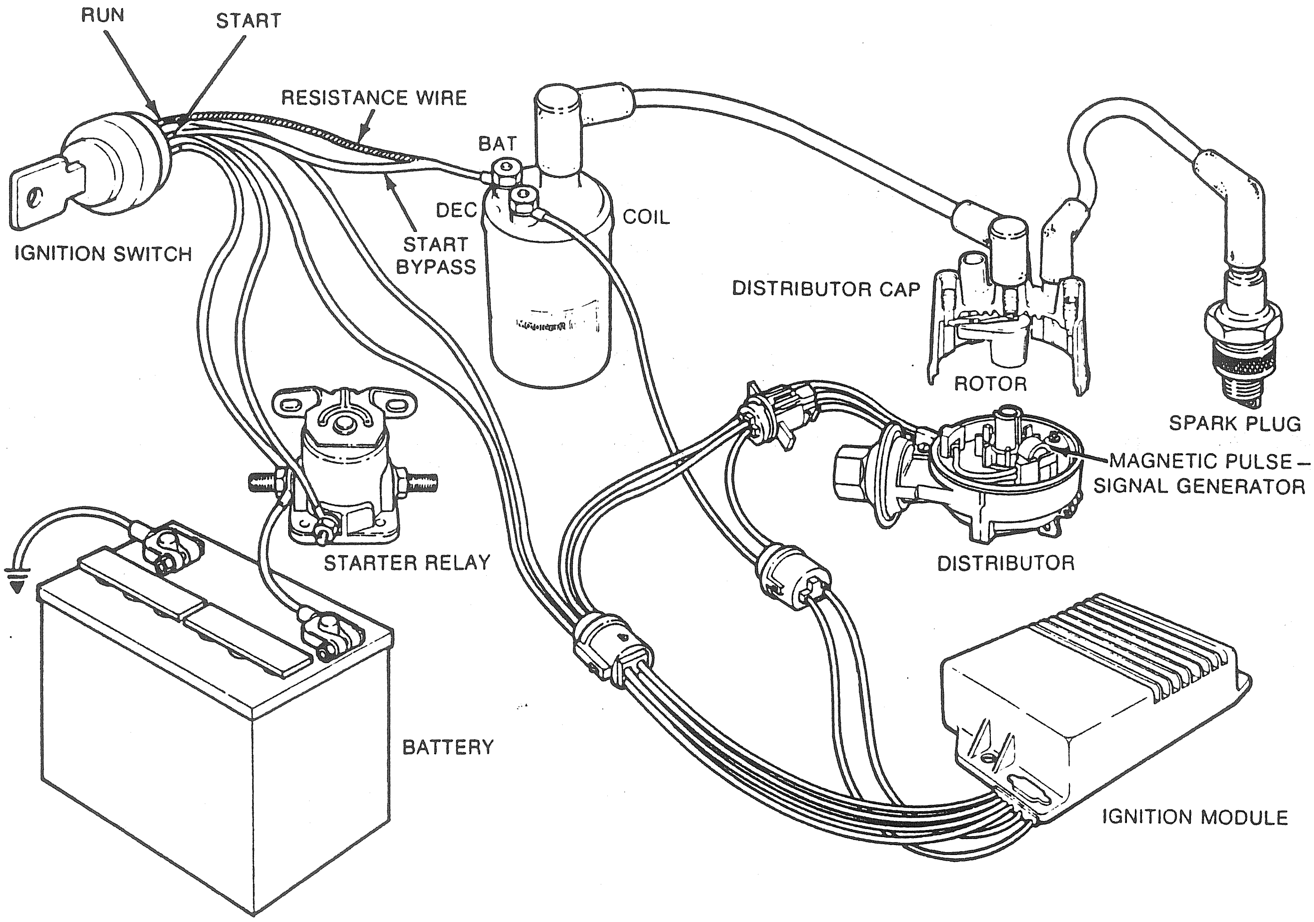


FIGURE 6–10
Components of the SSI system. (Courtesy of Ford Motor Co.)

eliminate deterioration of spark quality, which occurs in the standard system with wear or maladjustment of the contact points; to extend maintenance intervals even beyond those associated with the transistorized system; and to provide a more intense and reliable arc at the spark plugs for every firing impulse in order to ignite the lean mixtures needed for the control of emissions.

SSI System Design

The solid state ignition (SSI) system consists of a coil, rotor, distributor cap, secondary wires, module, and magnetic-pulse type distributor (Fig. 6-10). The coil is essentially the same one used on prior standard systems. However, the SSI coil has a blue case or tower, and the markings on the primary terminals are different. The negative (−) terminal is changed to DEC. A wire attached to this terminal leads into a harness from the ignition module. The wire from the ignition switch to the coil's BAT terminal has the same resistance of that used with a standard system, 1.30 ohms to 1.40 ohms.

The rotor and cap are black in color and made the same as those used in standard systems. The secondary cables also are the same 7-mm, hypalon-insulated material used in the prior system.

The *ignition module* (Fig. 6–11) is simply an electronic switching circuit. This unit turns the primary circuit current off and on in response to voltage pulses received from the magnetic-pulse distributor.

The module has seven electrical leads formed into two harnesses. The connector attached to the end of each harness permits easy replacement of the distributor pickup coil or the module itself.

The color coding for the electrical module leads is as follows.

Note: The color coding of the wires shown below are for the leads directly attached only to the ignition module. The colors of the wires in the connecting harness may or may not be the same.

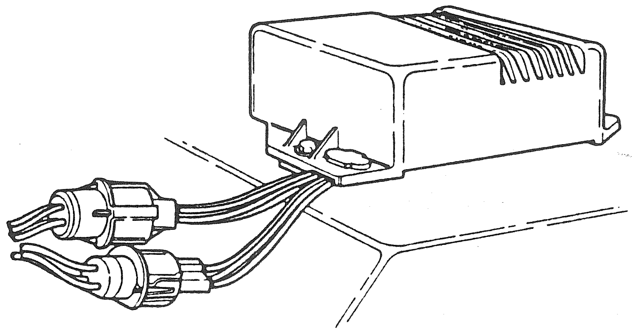


FIGURE 6-11
SSI ignition module. (Courtesy of Ford Motor Co.)

1. The green lead carries primary current from the coil's "DEC" terminal to the ignition module.

2. The black lead carries primary current flow from the ignition module to the ground connection in the distributor.

3. The orange and purple leads connect to the pickup coil within the distributor; they transmit voltage pulses from the pickup coil to the ignition module.

4. The red lead connects to the "RUN" terminal of the ignition switch. It provides the battery voltage and current flow to the module when the ignition switch is in the "RUN" position.

5. The white lead attaches to the "START" terminal of the ignition switch or to the "I" terminal of the starter relay. In either case, the lead carries battery current to the ignition module control circuits when the ignition switch is in the "START" position.

6. The blue lead attaches to the "BAT" terminal of the coil. This wire serves to bleed off any excessive voltage pulses that may occur in the module.

The magnetic-pulse distributor consists of a centrifugal and vacuum advance mechanism, an armature, and a magnetic pickup assembly (Fig. 6-12). The centrifugal advance mechanism is located under the fixed base plate and operates in the same manner as a similar device found in the standard ignition system distributor. The main and only difference is that the mechanism turns the armature ahead in the direction of distributor shaft rotation instead of point cam.

The vacuum advance attaches to the outside of the base casting and, with one exception, operates like a similar unit on a standard distributor. The difference is that this vacuum advance moves the magnetic pickup assembly in a direction opposite to distributor shaft rotation instead of the breaker plate.

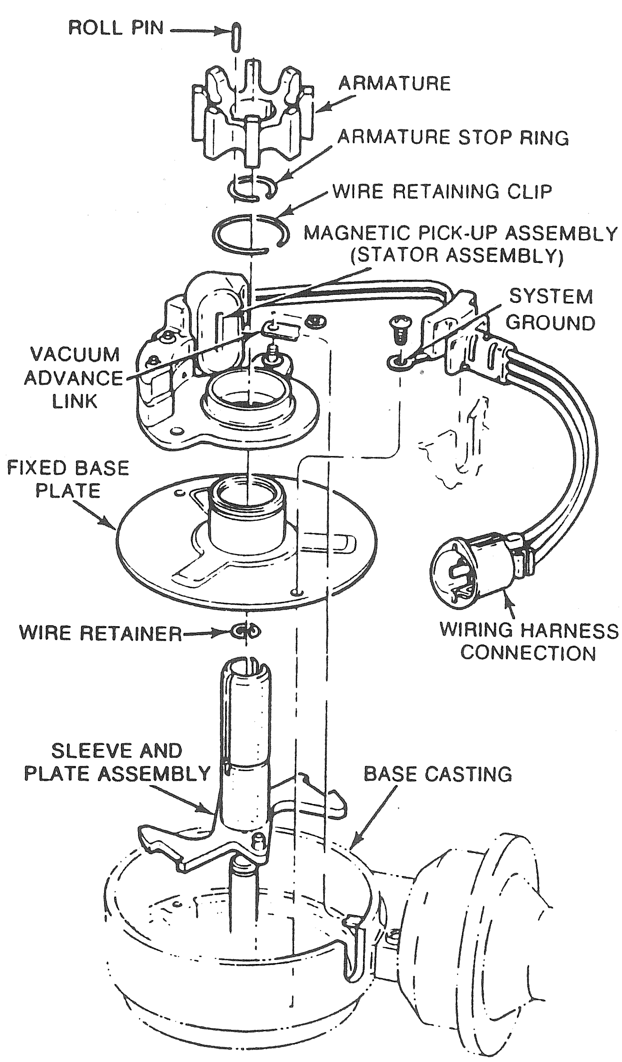


FIGURE 6-12
Design of the SSI distributor. (Courtesy of Ford Motor Co.)

The armature is a snug fit over the distributor shaft and is secured to it by a roll pin. The armature itself is made of ferrous metal (i.e., containing iron) that has low magnetic reluctance and, therefore, high permeability. The armature has teeth, projections, or spokes, one for each cylinder of the engine.

The magnetic pickup assembly consists of a coil and a weak, permanent magnet. The coil consists of a number of turns of fine insulated wire wrapped around the magnet. The magnet provides a fixed stationary magnetic field. If the strength (magnetic flux) of this field changes, it will induce a small voltage in the pickup coil. If no magnetic lines of force cut the coil, there will be no voltage induction.

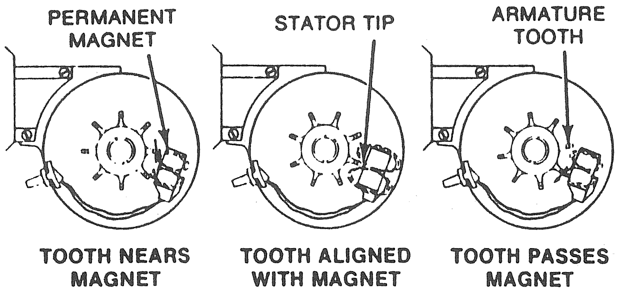


FIGURE 6-13
Operation of a magnetic-pulse generator. (Courtesy of Ford Motor Co.)

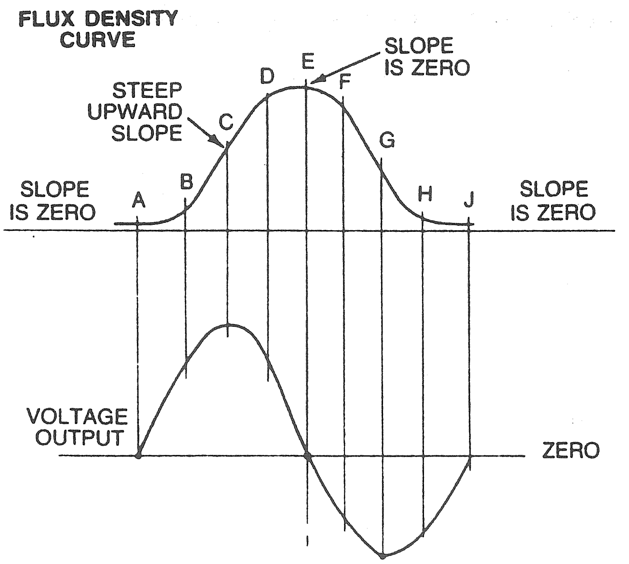


FIGURE 6-14
Voltage curve across pickup coil. (Courtesy of Ford Motor Co.)

Solid State System Operation

As the armature rotates with the shaft, the strength of the field of the permanent magnet varies (Fig. 6-13). When one of the teeth of the armature approaches the magnet, it reduces the reluctance, or magnetic resistance, near the field. This expands the magnetic field out of its normal position, causing the lines of force to cut the windings of the pickup coil. The field strength becomes strongest when the air gap is smallest, and the tip of a tooth is directly across from the magnet. The varying magnetic field induces a voltage in the pickup coil that is proportional to the rate of change of the field.

Figure 6-14 illustrates the voltage curve across the pickup coil as one armature tooth passes it. As the tooth passes by, it detours the magnetic

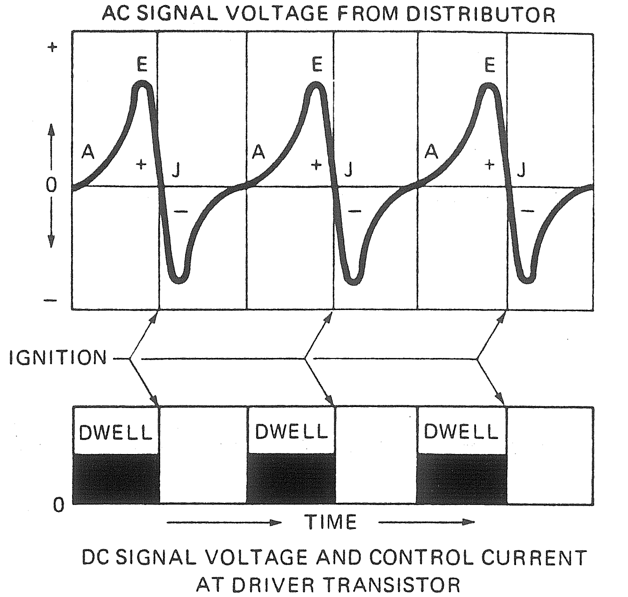


FIGURE 6-15
Electronic circuit converts AC pulses from the pickup coil to square wave DC pulses.

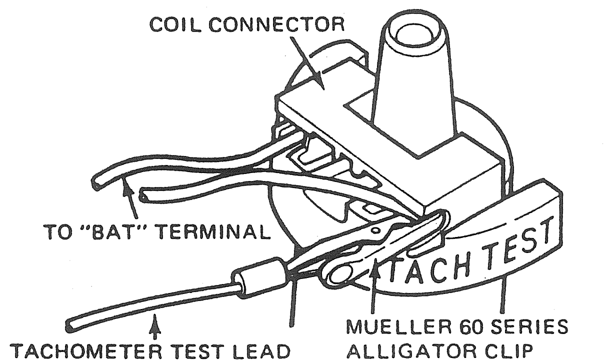


FIGURE 6-16
Ignition coil connector. (Courtesy of Ford Motor Co.)

lines of force from the permanent magnet inside the pickup coil. This changes the density of the lines of force through the coil. As mentioned, this generates a voltage proportional to the number of lines that are shifting at any particular instant. This is represented by an upward, positive voltage line from A to E.

At E, the armature tooth is directly across from the magnet. Even though the magnetic field strength is strongest at this point, the rate of change in the magnetic field density is zero at this point. That is why the voltage drops from positive to zero at J.

As the tooth passes the permanent magnet, a negative voltage is produced. The induced negative voltage is shown on the lower diagram and is due

to the collapse of the magnetic field to its original position.

As the pickup coil voltage induced by one tooth changes to negative polarity, another tooth approaches the magnet. This starts another positive voltage pulse in the pickup coil.

In the SSI system, both the positive and negative (AC) voltage (analog) signals are applied to the ignition module. *A circuit in the Duraspark III system converts these AC signals to DC square wave (digital) pulses* (Fig. 6–15).

In either case, the induction of a positive voltage in the pickup coil turns on the driver transistor. This closes the circuit to the primary coil, and current flows through its windings (the dwell period). However, at positive zero voltage, the transistor is turned off. During this time there is a collapse of the primary coil's magnetic field and the induction of high voltage in the secondary coil windings. The white boxes following those in black depict the dwell periods and represent the transistor-off periods for modules using DC square wave signals.

As the distributor turns faster and the frequency of the AC signal to the module becomes greater, the time span between positive voltage (transistor-on) pulses becomes shorter. The ignition module has built-in timing circuits that maintain optimum coil build-up times between these pulses. In effect, the module tailors the dwell to produce a secondary voltage output from the coil that is constantly high.

1975 Solid State System Modifications

In 1975, there were no changes that altered system operation. There were, however, some design changes.

The ballast resistance was slightly reduced to 1.25 ohms to 1.35 ohms. This increased the current flow through the primary windings in order to raise the secondary available voltage at the plugs. The internal components of the ignition module were upgraded to handle the increased primary current flow. In addition, a new blue material was used for the distributor cap and rotor to insulate them from leakage due to higher secondary voltage. The ignition module connectors were altered in order to prevent the use of 1974 modules in 1975 systems.

A new, polarized coil, primary circuit connector was used in order to prevent the installation of the leads in reverse polarity (Fig. 6–16). Also, the DEC terminal of the coil connector was changed to read TACH TEST. This new connector permits a tachometer test lead having an alligator clip to be installed onto the distributor electronic control terminal without removing the connector. In addition, silicone insulation was used on some ignition cables to compensate for increased engine compartment heat on emission-controlled engines.

1976 Solid State Ignition System Modifications

In 1976, there were again no major changes in the basic operation of the system (Fig. 6–17). However, there were a few design changes.

Due to internal improvements within the ignition module, the blue overload shunt lead was no longer required and thus eliminated. The ignition module now has six leads instead of seven. The ignition module connectors were revised to reflect the reduction from seven to six leads. The use of silicone-insulated ignition cables was applied to more vehicles.

6-4 FORD DURASPARK I IGNITION SYSTEM

In 1977, Ford altered the basic SSI system to increase its available secondary voltage. Along with a number of design changes, Ford also changed the name to the Duraspark ignition system. There have been three variations of this system so far, each operating in a manner similar to the solid state system just discussed.

The Duraspark I system was used only in California from 1977–1979 on the 5.0-liter engine (Fig. 6–18). The system produced a much higher secondary voltage than the Duraspark II design, which is discussed in the next unit.

Coil Design

The higher secondary voltage is accomplished through the use of a high output coil. This special coil contains windings that have a much lower resistance, thus permitting a higher current flow. The core of the coil is also designed to accept a much higher magnetic charge from the higher current.

The ballast resistor is eliminated, so the system uses a full 12 volts across the primary windings. As a result, there is not only a speeding up of the build-up time but also an increase in the strength of the magnetic field around the primary windings. This has the effect of producing a much higher voltage in the secondary coil.

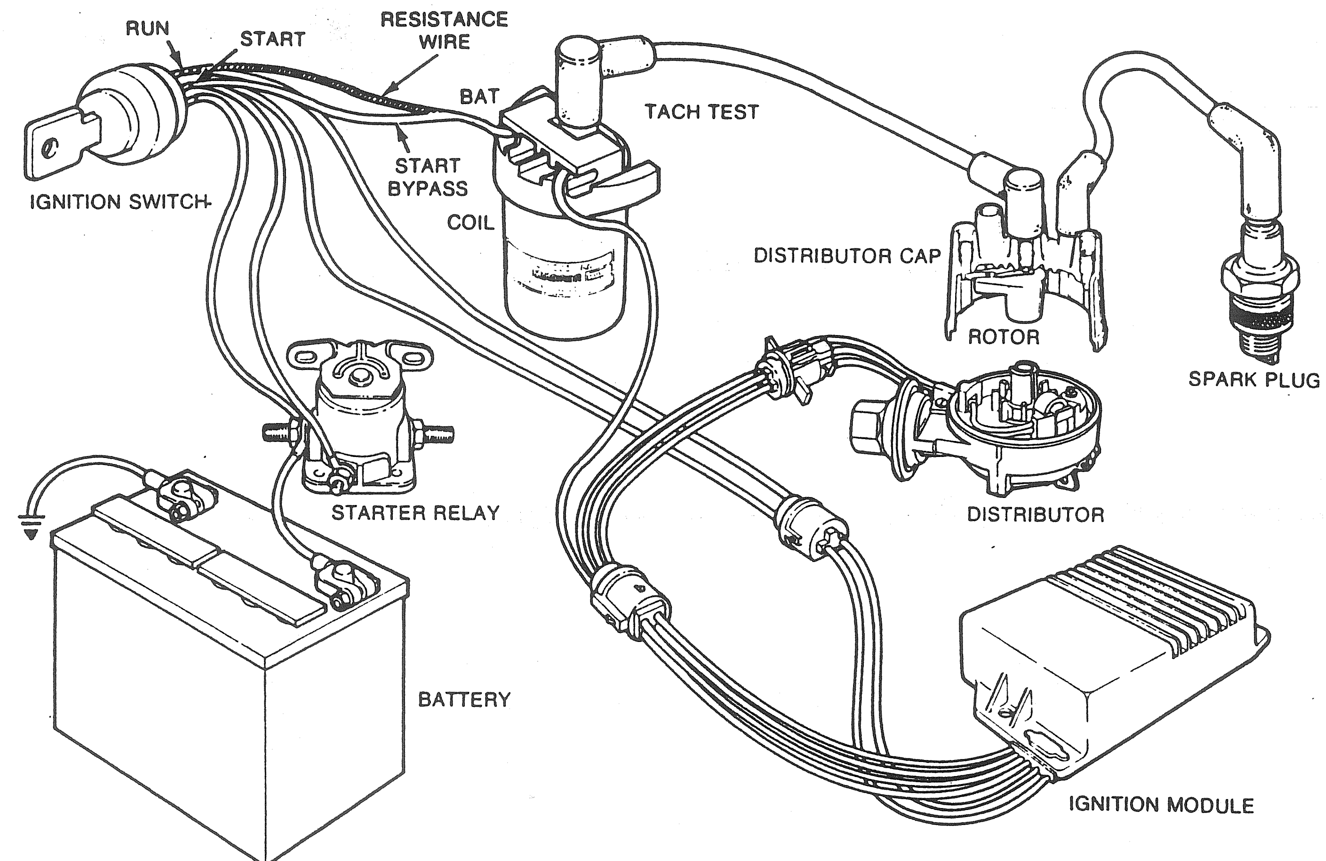


FIGURE 6-17
Design of the 1976 SSI system. (Courtesy of Ford Motor Co.)

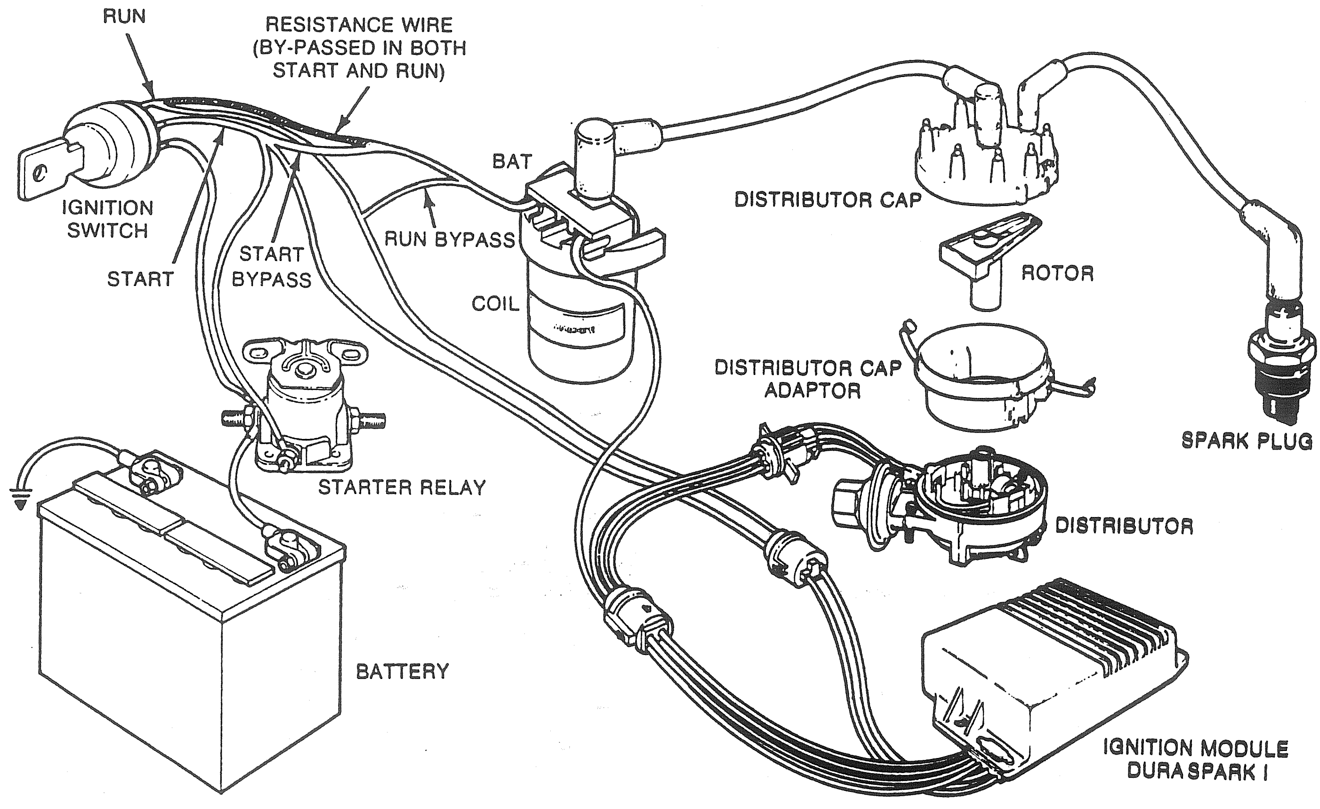


FIGURE 6-18
Design of the Duraspark I system. (Courtesy of Ford Motor Co.)

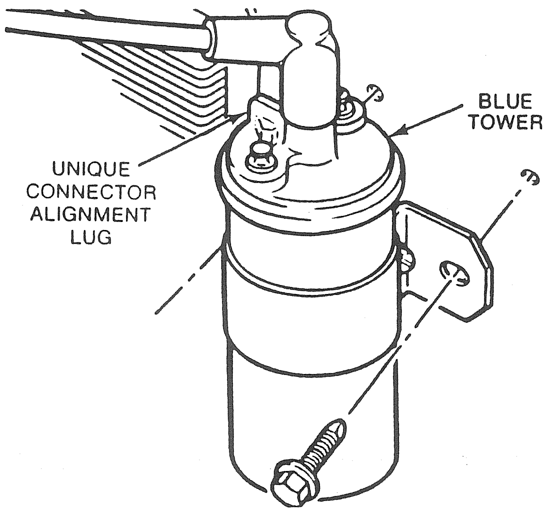


FIGURE 6-19
Duraspark I coil has an alignment lug. (Courtesy of Ford Motor Co.)

The coil has a unique alignment lug on the blue coil tower (Fig. 6-19). This prevents the coil from being attached to the harness of a basic solid state ignition system.

Design of the Cap and Rotor

To insulate the increased secondary voltage, a new, larger distributor cap with male-type spark plug contacts is used (Fig. 6-20). This, of course, requires a longer and higher rotor. The increased space between the cap cable contacts reduces the chance for arcing between adjacent inside terminals, or from the rotor to the wrong terminal.

To fit the larger cap and rotor to the distributor body, an adapter collar is installed between the body and the cap. Also, the distributor body uses centrifugal and vacuum advance units similar to those on a solid state ignition distributor.

Design of the Ignition Cables and Spark Plugs

The ignition cables are insulated with silicone, as indicated by the blue color, to resist higher engine compartment temperatures caused by the emission control systems. Furthermore, to insulate against the loss from leakage due to increased secondary voltage, the ignition cable size is increased from 7 mm to 8 mm.

The spark plugs used with the Duraspark I system are not the same as those used with SSI. The plugs themselves have a −6 suffix, and they are set to a wider gap.

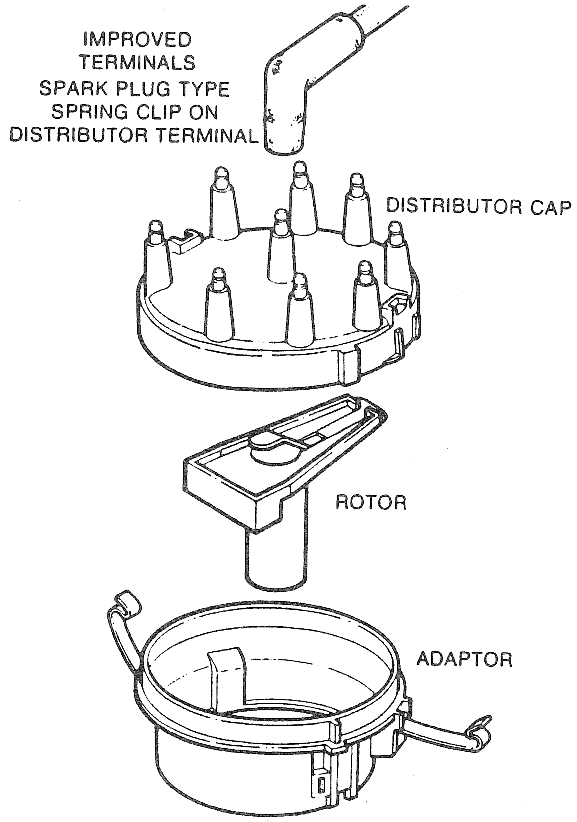


FIGURE 6-20
Cap and rotor used on Duraspark systems. (Courtesy of Ford Motor Co.)

Design of the Module

In the Duraspark I system, spark intensity is greatly increased, especially at higher engine rpm. If the coil were permitted to run with the same dwell control (maximum build-up time) as in the basic SSI system, the coil would, at lower rpm, overcharge and overheat. For this reason, the module of this system has a special current control.

This circuit senses the current flow in the primary windings just prior to each discharge of the coil. If the sensor reads more than a full charge within the coil, it delays the turn on of the primary circuit for the next dwell cycle of the coil. On the other hand, if the sensor reads a less than full charge, it turns on the primary circuit slightly sooner for the next dwell cycle.

This action holds the time during which the primary circuit is on to the period needed to fully charge the coil for every discharge. In this way, the module constantly tailors the length of the dwell to the requirements of the system and to engine speed. Dwell then varies with respect to the degrees of crankshaft rotation but remains relatively constant with respect to actual coil build-up time.

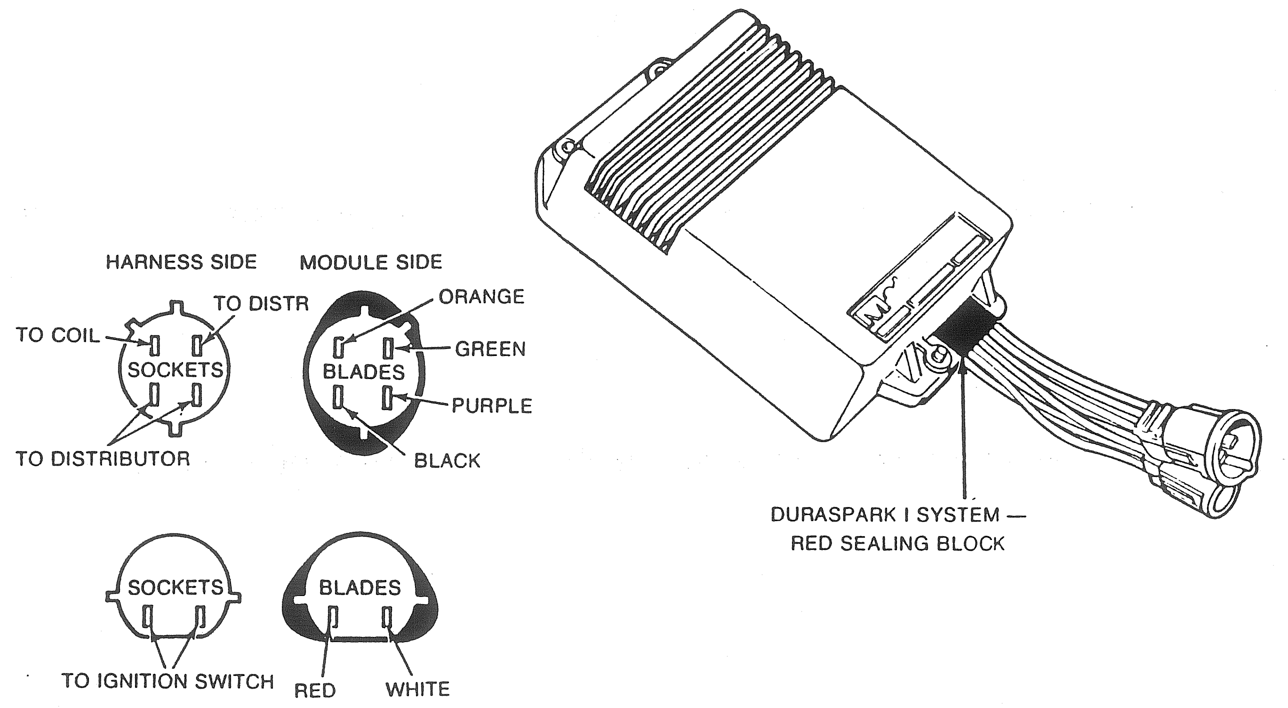


FIGURE 6-21
Module used on a Duraspark I system. (Courtesy of Ford Motor Co.)

The current-control circuitry also shuts off the primary current flow if the engine stalls. Therefore, the ignition switch must be turned to start in order to shift the module back into the operating mode.

In appearance, the module is identical to the basic SSI unit. It has the same six leads. However, the sealing block through which the leads enter the module is red in color. The block for the SSI module is blue. In addition, to prevent an interchange with other system modules, the connector keyway on the Duraspark I module is different. Figure 6-21 illustrates the Duraspark I module for 1977-1979.

6-5 FORD DURASPARK II IGNITION SYSTEM

Ford also developed the Duraspark II system in 1977 and used it much more extensively than Duraspark I (Fig. 6-22). The Duraspark II system produces a higher voltage than SSI but less than Duraspark I. The system uses the same distributor, cap, rotor, and ignition cables as Duraspark I. The system uses the SSI coil and spark plugs, but the gaps are increased on some models.

Ballast resistance is decreased from the 1.25 ohms to 1.35 ohms used with the 1975-1976 SSI system to 1.05 ohms to 1.15 ohms. This permits an increase in primary current that substantially raises the secondary available voltage. However, the module required upgrading to handle the increased flow of primary current.

1978 Duraspark II Modifications

In 1978, the Duraspark II underwent a number of modifications. An electronic engine control system (EEC-I) was introduced on 5.0-liter (302 CID) V-8 engines installed in Versailles automobiles. This system covers a number of other engine functions and will be discussed in another chapter. In addition, dual-mode ignition modules and sensors were installed on some models that were manufactured for certain geographical areas.

Dual-Mode Ignition for Duraspark II Systems

There are two types of dual-mode ignition systems in use (Fig. 6-23). One system is for altitude compensation, while the other is for economy calibration. Both use the same ignition module.

The altitude system provides compensation on some vehicles that normally operate at altitudes above 4,000 feet (1,219 meters). On these installations, the carburetor is set lean for operation at a higher altitude with a normal spark advance setting. Below the specified altitude, a barometric pressure switch within the system provides an input signal to

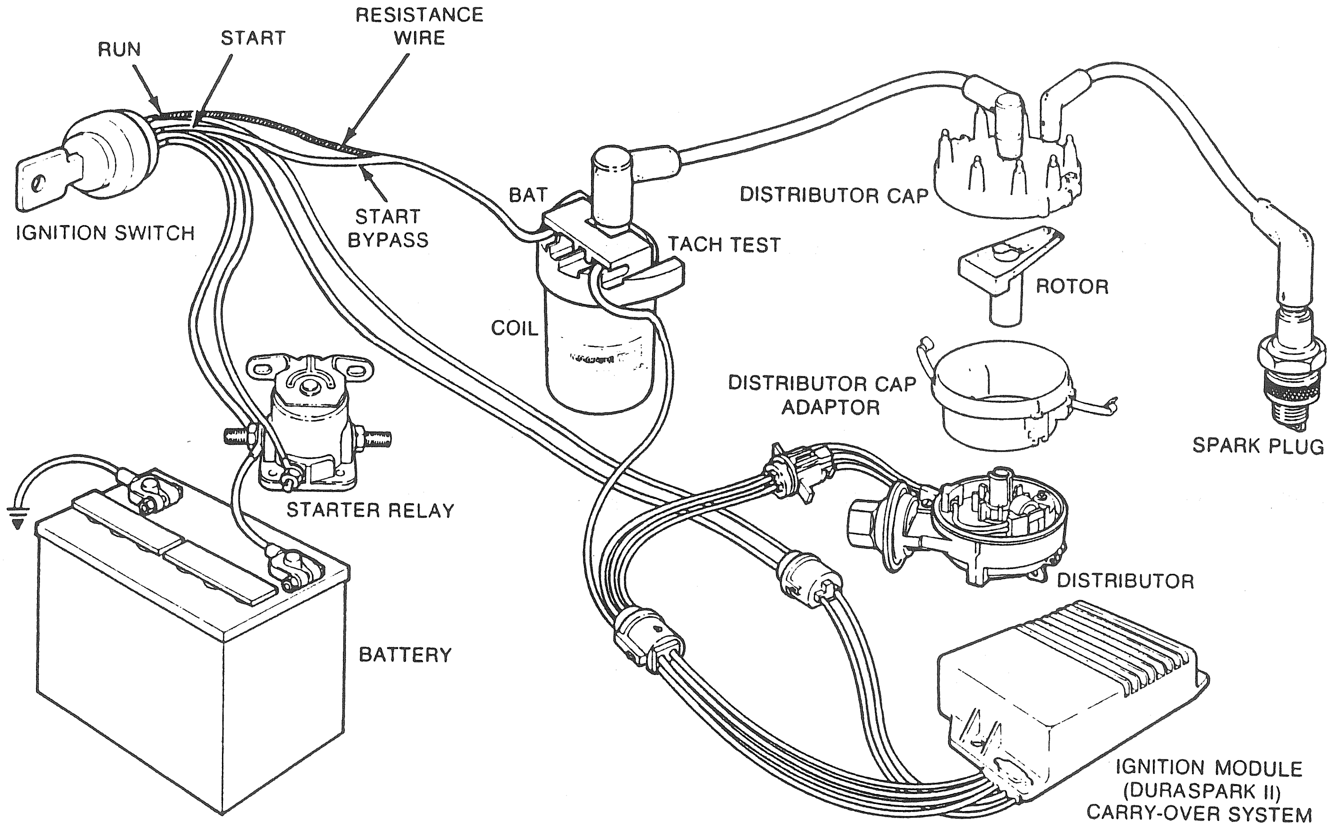


FIGURE 6-22
Design of the Duraspark II system. (Courtesy of Ford Motor Co.)

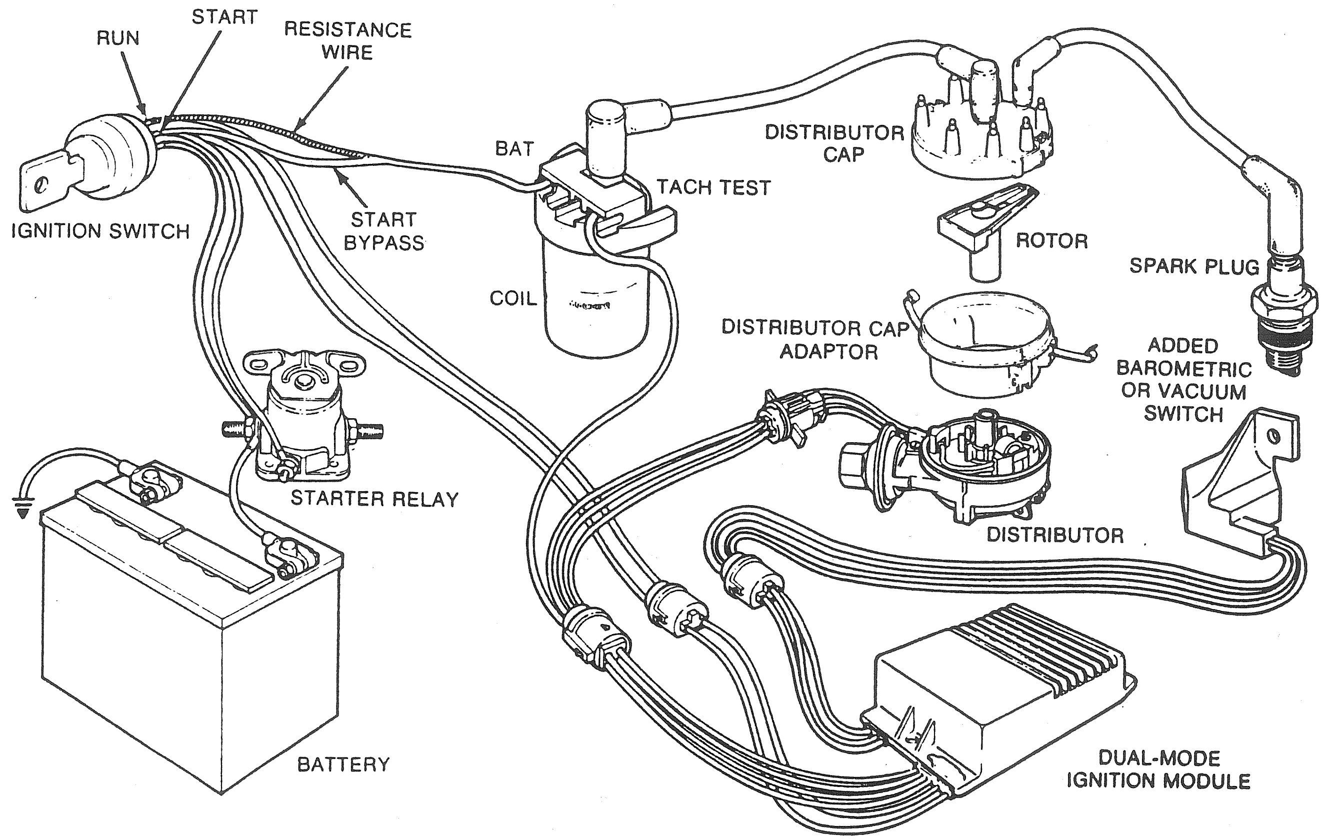


FIGURE 6-23
Dual-mode, Duraspark II system. (Courtesy of Ford Motor Co.)

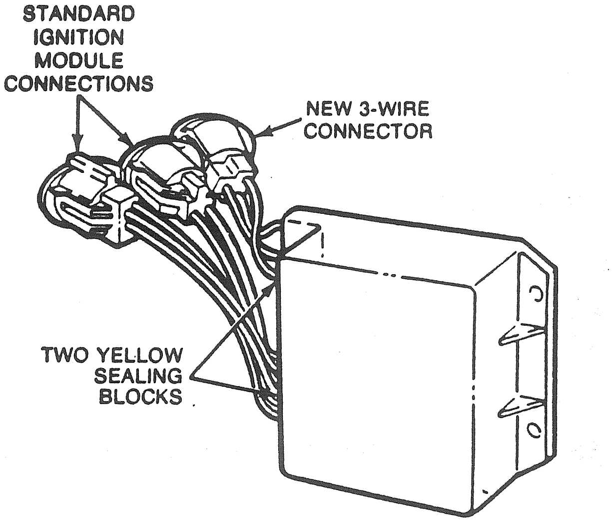


FIGURE 6-24
Dual-mode, Duraspark II ignition module. (Courtesy of Ford Motor Co.)

the ignition module. This causes the module to retard the spark timing by three to six degrees to prevent detonation from the overly lean mixture at lower altitudes.

The economy system provides calibration on a number of vehicles that operate at altitudes of sea level to 3,000 feet (914 meters). In this case, the carburetor is also set lean, while the initial spark timing is advanced for the greatest economy under a light engine load (cruise conditions). When the driver opens the throttle for acceleration or hill climbing, a vacuum switch senses the drop in engine vacuum and provides an input signal to the module. The module then retards the spark timing by three to six degrees to prevent detonation. This is in addition to the normal retard caused by a loss of vacuum to the vacuum advance during acceleration.

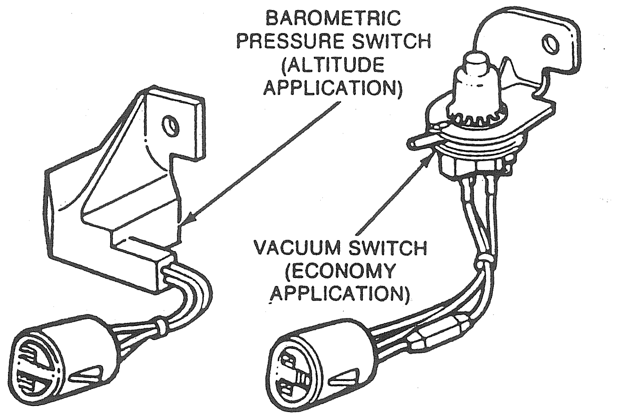


FIGURE 6-25
Barometric and vacuum switches for the dual-mode ignition system. (Courtesy of Ford Motor Co.)

The system itself consists of all the Duraspark II components plus a special ignition module. The module has three extra leads, making nine in all, and has yellow sealing blocks (Fig. 6-24). Either the barometric pressure switch or the vacuum switch (Fig. 6-25) may be plugged into these three extra leads on the module. In other words, the same module serves both the economy and altitude compensation applications. When the barometric or vacuum switches are not activated, the ignition module and the system operate in a normal manner.

There is one thing to remember about dual-mode installations. *When checking or adjusting initial spark timing, the barometric or vacuum switch must be unplugged from the module.*

1979 Duraspark II System Modifications

The Duraspark II underwent a number of modifications in 1979. An electronic engine control system (EEC-II) was installed with Duraspark II on Fords with the 5.8-liter (351W CID) V-8 engines built for use in California only. Mercury models with the same engine used the same arrangement in all 50 states. The EEC-II system will be discussed in a later chapter.

In addition, in non-turbocharged 2.3-liter engines with an automatic transmission, a cranking retard circuit was built into a special ignition module (Fig. 6-26). This retard feature is only actuated dur-

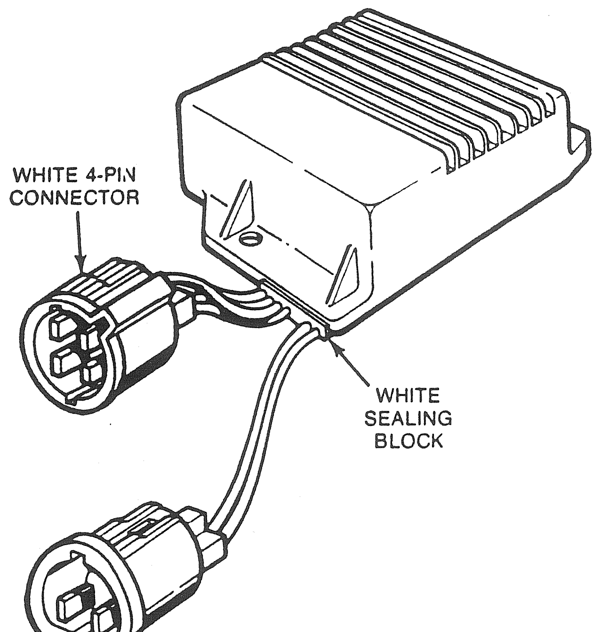


FIGURE 6-26
Cranking retard module. (Courtesy of Ford Motor Co.)

ing engine start-up by the slow rpm signal from the distributor's magnetic pickup. The signal activates a circuit in the ignition module to retard ignition timing up to 18 degrees to improve engine starting.

The ignition control module with the cranking mode is easily identified by the white four-pin connector in place of a black one. Also, the unit has a white sealing block where the wires from the connectors enter the module. The module is not functionally interchangeable with other units.

Universal Ignition Module

In 1981, Ford released a universal ignition module (Fig. 6-27). This unit is similar to the cranking retard module. However, it has a programmable run-retard feature in a smaller, compact Duraspark module. The module can be identified by a yellow grommet plus an extra three pin connectors.

The run-retard function may be programmed by an external switch. The switch changes resistance combinations inside the module to determine the actual amount of timing compensation the module will make for altitude and economy. The module switch may also be used as a variable control in a closed loop system.

6-6 FORD DURASPARK III IGNITION SYSTEM

In 1978, Ford developed the Duraspark III system to be used only in conjunction with electronic engine control systems. The ignition module used with Duraspark III is similar in appearance to those on the other Duraspark systems. However, some of the electronic circuitry has been eliminated in the new unit. This circuitry is no longer necessary because the processor assembly, or electronic control assembly (ECA), in an electronic engine control system performs these functions instead of the ignition module (Fig. 6-28).

Another unique feature of the Duraspark III system is the elimination of the centrifugal and vacuum advance mechanisms from the distributor. Consequently, engine timing is not controlled by the distributor as in prior systems but by the ECA. The only task that the distributor performs is the distribution of secondary voltage from the coil to the spark plugs. The ECA signals the ignition module when to break the coil primary circuit, which generates the secondary high voltage at the coil.

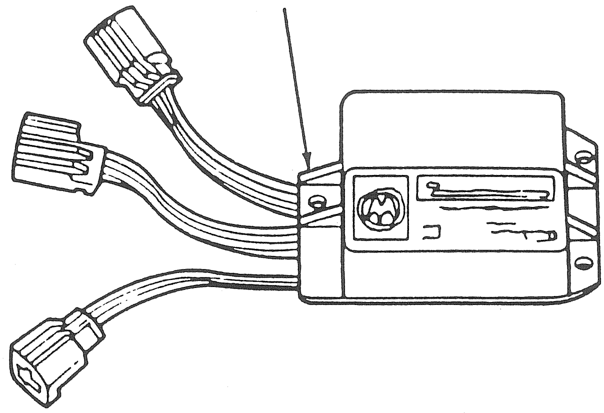


FIGURE 6-27
Universal ignition module. (Courtesy of Ford Motor Co.)

Design and Operation of the Crankshaft Position Sensor

The Duraspark III distributor contains no pickup coil and armature. But in order for the ECA to control ignition timing, it has to receive information about when each piston reaches the top dead center (TDC) position within the cylinder. To accomplish this action within the Duraspark III system, Ford introduced a *crankshaft position (CP) sensor.* This device senses crankshaft position that directly relates to piston location within the cylinder.

The CP sensor on the Duraspark III system, as used with some EEC-I systems, mounts on the rear of the engine block (Fig. 6-29). The tip of the sensor contains a permanent magnet and a coil of wire.

The CP sensor is secured in place by a retaining clip and screw. An O-ring, near the tip of the sensor, seals the lower opening in the rear of the engine block. Once the sensor is locked in place, no field adjustment is necessary.

In place of the armature used with Duraspark distributors, this system has a *pulse ring.* This device does the same task as the armature, just a little more accurately. The ring itself is formed of steel approximately ¼ inch (6.35 mm) thick, and has four equally spaced lobes 90 degrees apart (Fig. 6-30). The assembly presses onto the rear end of the crankshaft.

Pulse ring position on the crankshaft is critical because it establishes engine reference timing. Ring placement is such that one of its lobes is positioned on the crankshaft 10 degrees in advance of the TDC point. This determines the engine reference (basic) timing at 10 degrees before top dead center (BTDC).

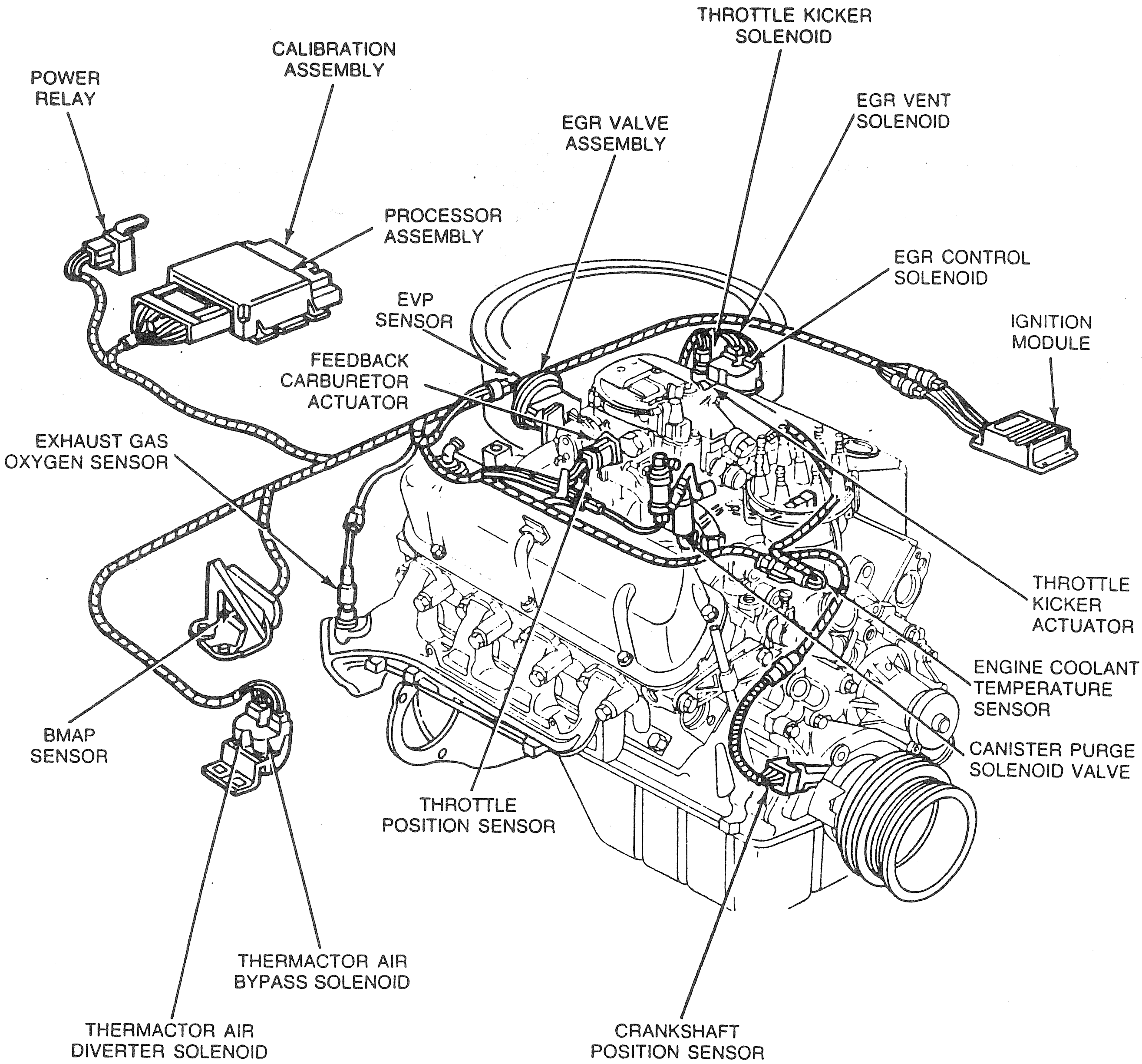


FIGURE 6-28
Duraspark III ignition used with an electronic engine control system. (Courtesy of Ford Motor Co.)

Moreover, once the pulse ring is pressed on during crankshaft manufacturing, it can never be removed or adjusted. Since the crankshaft rotates twice to each distributor shaft rotor revolution, only four lobes are necessary for V-8 engine ignition.

The CP sensor aligns with the crankshaft pulse ring. The sensor identifies the actual position of the crankshaft through the pulse ring lobe. In other words, the CP sensor coil, magnet, and ring operate like a distributor pickup coil and armature in previous systems to produce an AC sine wave signal.

In operation, as the crankshaft rotates, the individual pulse ring lobes approach and finally align with the sensor tip. This action produces the AC voltage signal to the ECA for analysis (Fig. 6-31). The CP voltage pulses determine crankshaft position, while its signal frequency provides engine rpm information.

The ECA is the control center for the system. It interprets and decodes the electrical input pulses from the CP sensor. The ECA uses this crankshaft position and rpm data for spark timing and ignition advance calculations. This eliminates the need for a distributor centrifugal advance mechanism. The

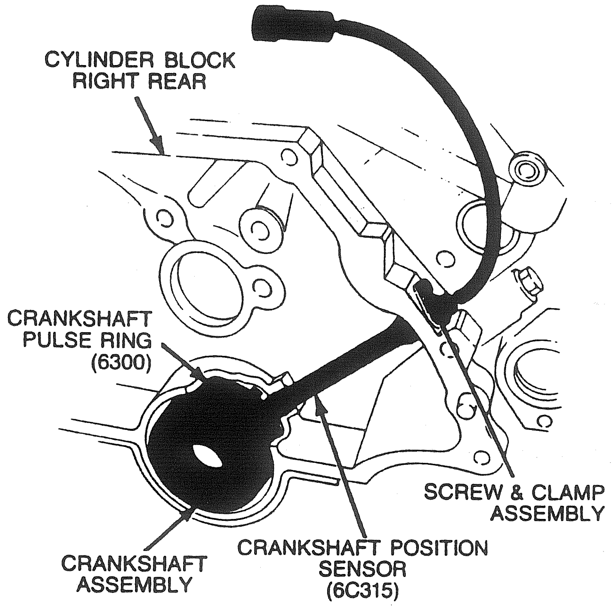


FIGURE 6-29
EEC-I, Duraspark III CP sensor and pulse ring. (Courtesy of Ford Motor Co.)

ECA also has input data from sensors that read engine vacuum as well as many other engine conditions. Therefore, there is no longer any need for a distributor vacuum advance mechanism.

The ECA has a circuit that converts the AC sine wave signal to the DC square wave pulse. This produces very precise information on crankshaft position for spark timing, and on rpm data for timing advance. However, the ECA directs this DC signal to the ignition module during a positive zero voltage signal from the CP sensor (see J of Fig. 6-14). When you consider the facts, it is not surprising that the ECA can then put out an extremely accurate ignition timing signal to the ignition module regarding when to open the primary circuit.

Function of the Duraspark III Ignition Module

The Duraspark ignition module actually opens the primary coil circuit. The resulting collapse of the field induces high voltage in the secondary windings of the coil. As the crankshaft turns faster and the frequency of the AC signal from the CP sensor becomes greater, the time span between pulses becomes shorter. The ignition module has built-in timing circuits that maintain optimum coil charging time between pulses. In effect, it is like the early modules that tailored the dwell (coil-on) time to produce a constant, high, secondary voltage.

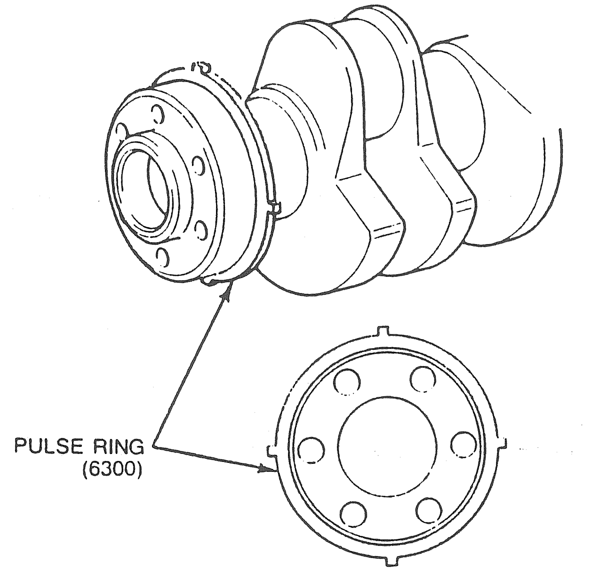


FIGURE 6-30
Design and location of the pulse ring. (Courtesy of Ford Motor Co.)

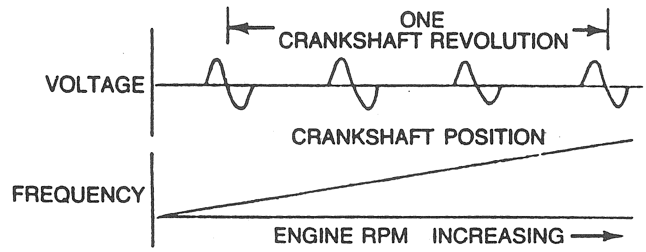


FIGURE 6-31
CP voltage pulses and frequency. (Courtesy of Ford Motor Co.)

If for any reason there is a failure in the ECA, the system goes into a *default mode.* In this mode, the engine operates with no additional spark advance, other than initial timing, regardless of sensor input signals. The vehicle can be operated until repairs are made, but engine performance is poor.

Bi-Level Rotor and Distributor Cap

Since the ECA used with the EEC-I system allows up to 30 degrees of ignition advance, Ford redesigned the distributor rotor and cap for the Duraspark III distributor. The new design allows for the additional advance capability without a problem of crossfire or need for a mechanical advance mechanism.

In early distributor designs, the cap firing order followed the circular path of the rotor. However, in the Duraspark III distributor, upper and lower

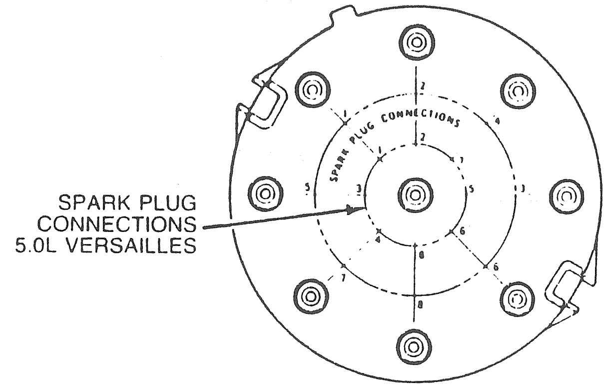


FIGURE 6-32
Inside view of the distributor cap. (Courtesy of Ford Motor Co.)

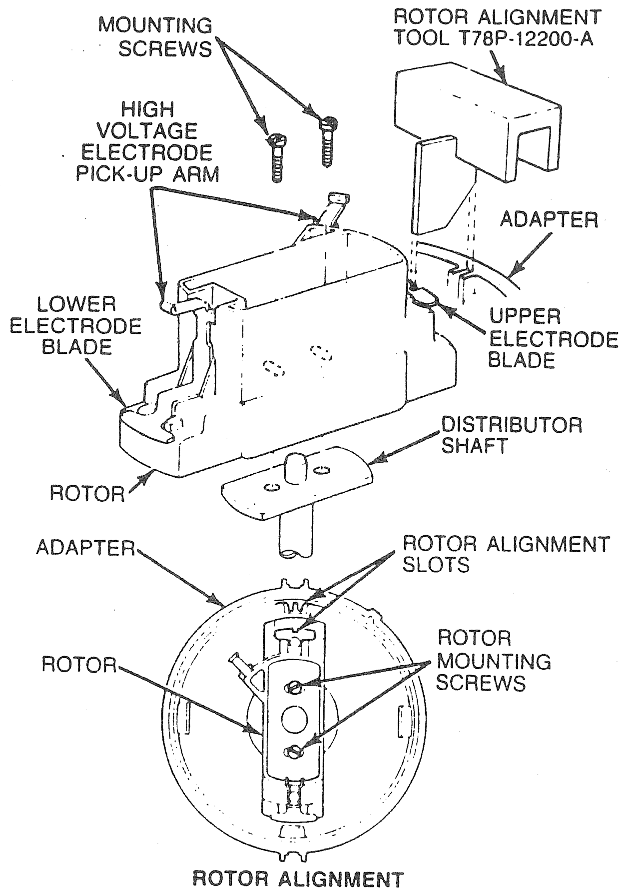


FIGURE 6-33
Duraspark III rotor. (Courtesy of Ford Motor Co.)

electrodes fire alternately in a pattern that jumps from one side of the cap to the other (Fig. 6-32).

In other words, the bi-level rotor and distributor cap have two separate levels of secondary voltage distribution (Figs. 6-33 and 6-34). As the rotor turns, one of the pickup arms aligns with one spoke of the distributor cap's center electrode plate. This

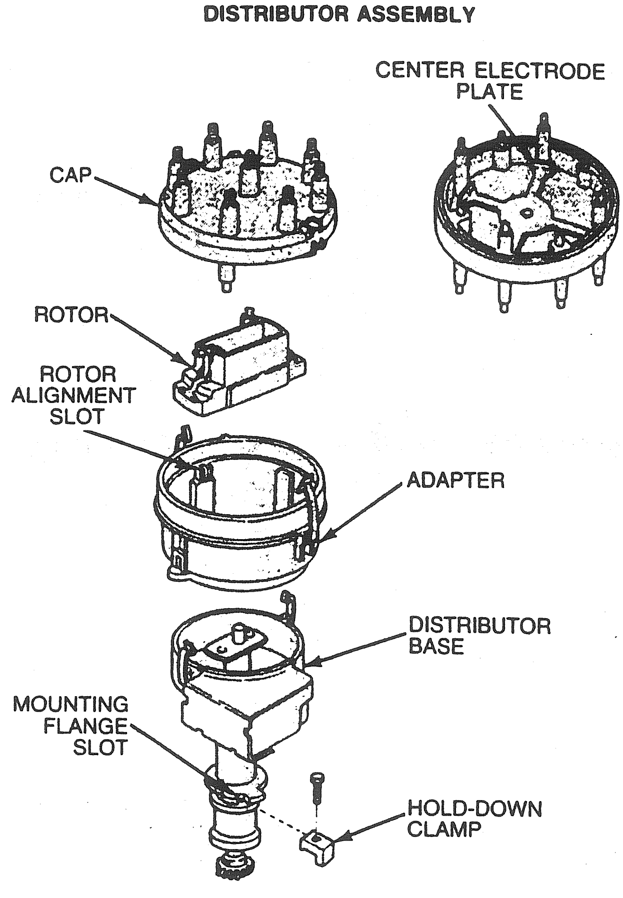


FIGURE 6-34
Duraspark III distributor. (Courtesy of Ford Motor Co.)

allows the high voltage to transfer from the plate, through the rotor, and then to the distributor cap, plug wire, and finally to the appropriate spark plug.

The relationship between the distributor base and the engine are important for proper dispersing of high voltage. For this reason, the Duraspark III distributor secures to the engine using a special type of slotted, hold-down flange and clamp.

The housing and cover on the side of the distributor case (Fig. 6-34) provide an enclosure for a future miniaturized version of the ignition module. Units with this design are known as *universal distributors.*

1979 Modifications to the Duraspark III System

In 1979, Ford introduced the EEC-II system. This brought about a few changes in the Duraspark III system, mainly to the location of the CP sensor and pulse ring.

The CP sensor, even though it operates the

same, has a different location and design. The sensor is now located in the front of the engine block, down near the crankshaft, instead of in the rear of the engine (Fig. 6–35). It also has an extra connector, which is necessary for shielding against electrical interference that can cause false or improper signals.

In addition, the pulse ring, instead of being mounted to the rear of the crankshaft, is moved to the front (Fig. 6–36), where it is pressed onto the crankshaft vibration damper. Once the pulse ring is installed onto the damper during manufacturing, it can never be removed or adjusted.

As in the EEC-I system, a default mode is used if there is a failure in the system. However, for EEC-II, this condition is known as *limited operational strategy (LOS)*.

Finally, the EEC-II system allows a timing advance of up to 36 degrees. The distributor continues to use the bi-level rotor can cap.

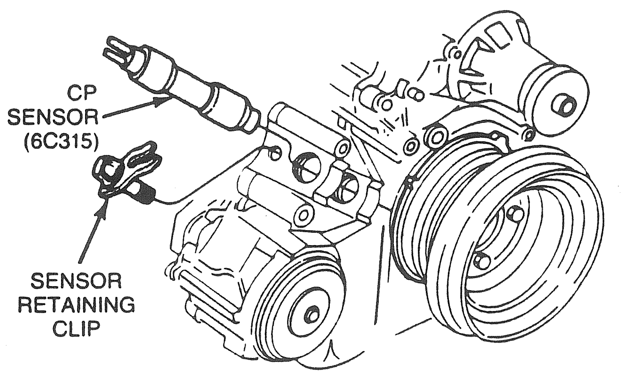


FIGURE 6–35
Location of the CP sensor in EEC-II systems. (Courtesy of Ford Motor Co.)

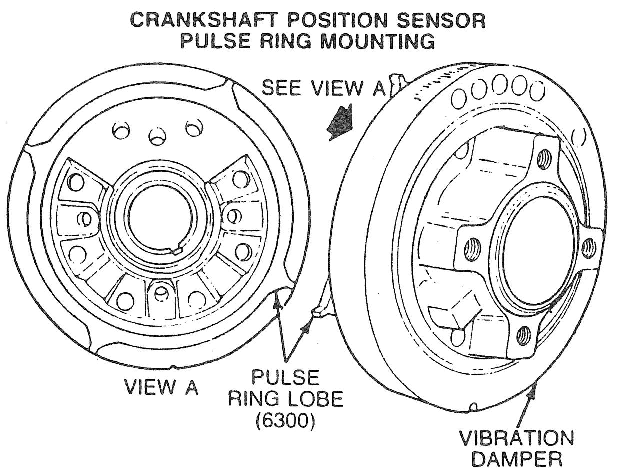


FIGURE 6–36
Location of the CP sensor in EEC-II systems. (Courtesy of Ford Motor Co.)

1980 Modifications to the Duraspark III System

In 1980 Ford introduced the EEC-III system. The only ignition system change is in the rotor and cap (Fig. 6–37). The second generation of bi-level distributor is designed not only to handle increased amounts of timing advancement but also for improved serviceability. The revised design allows rotor replacement without requiring rotor realignment.

The new rotor is also a bi-level design, but instead of being rectangular in design, it is cone-shaped. The center electrode of the distributor is also redesigned.

6-7 FORD THICK-FILM INTEGRATED-I IGNITION SYSTEM

Ford introduced its Thick-Film Integrated-I (TFI-I) ignition system in 1982 for 1.6-liter engines without an electronic engine control system. Electronically, its operation is very similar to Duraspark II. One major difference is that the TFI-I module is mounted directly into the base of the universal distributor assembly (Fig. 6–38). This arrangement eliminates the requirement for a wiring harness and connectors between the module and the distributor. The TFI-I module is also much smaller than a Duraspark unit. These factors combine to reduce the size of the entire TFI-I system.

A modified pickup coil and armature are used; therefore, the system does not have a CP sensor. The TFI-I module opens and closes the circuit to the primary coil windings using an AC sine wave signal. The unit opens the circuit when the pickup coil produces a positive zero voltage.

Since the system does not operate in conjunction with an electronic engine control, ignition advance and retard functions are performed by vacuum and centrifugal advance mechanisms.

Another significant difference between the TFI-I and early Duraspark systems is that the former does not have a ballast resistor. This allows more current to flow through the primary windings, thus producing a higher voltage in the secondary.

TFI-I also features a different type of coil, known as the *E coil* (Fig. 6–39). This coil takes its name from the E-shape of the laminations making up its core. The E-core coil has a higher energy transfer because the laminations provide a closed magnetic path.

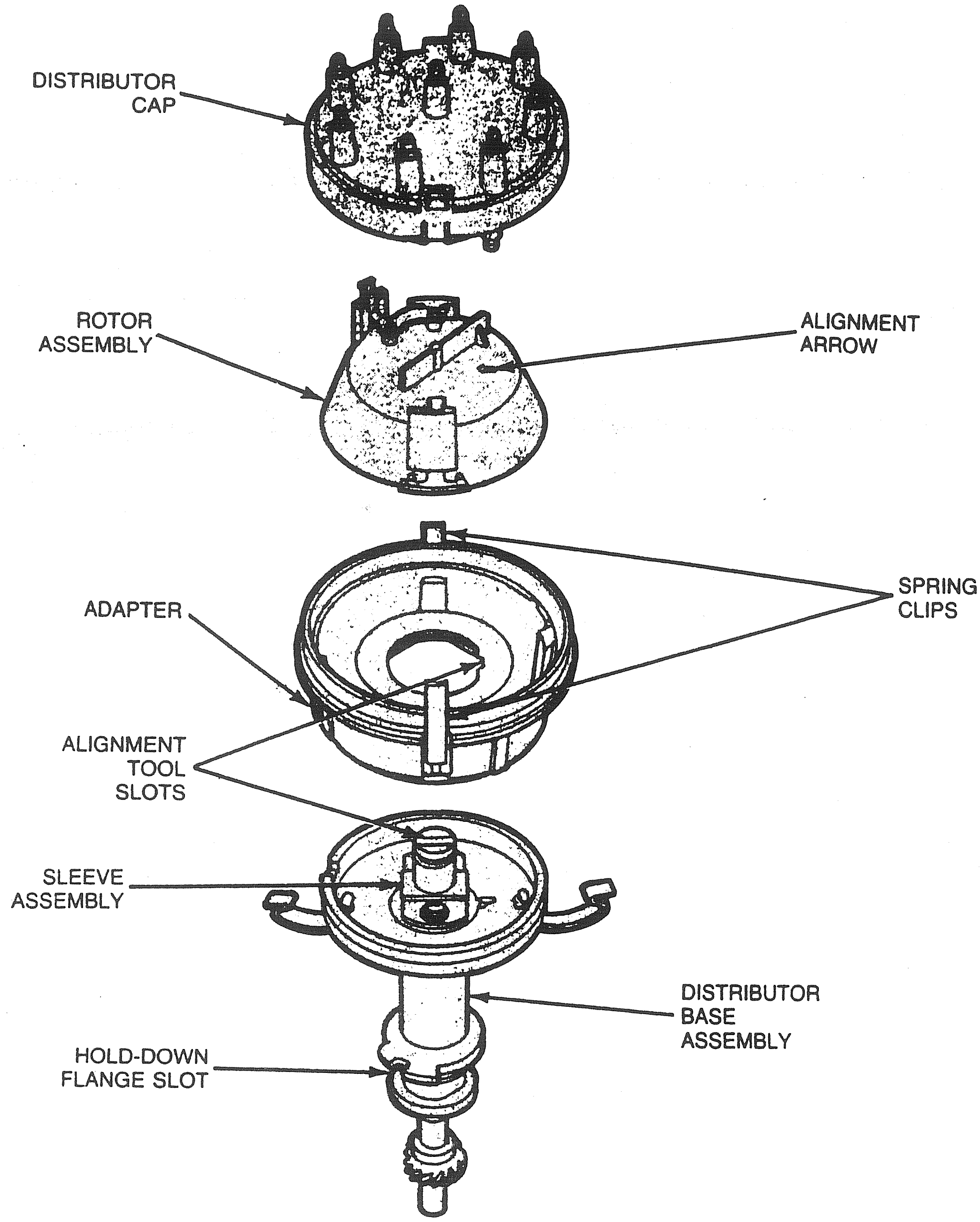


FIGURE 6–37
Second-generation distributor assembly. (Courtesy of Ford Motor Co.)

The TFI module requires a crank-mode signal for starting. For this reason, vehicles with TFI-I ignition cannot be push-started.

1983 TFI-I Modification

The 1983 TFI-I ignition has a slightly different rotor than the 1982 system (Fig. 6–40). The 1982 rotor's solid electrode is replaced by a unit with a two-pronged tip. This eliminates the need for silicone grease on the electrode to reduce radio noise. Also, if the rotor requires replacement, rotor alignment is not necessary. The early style rotor and the two-pronged unit are not interchangeable.

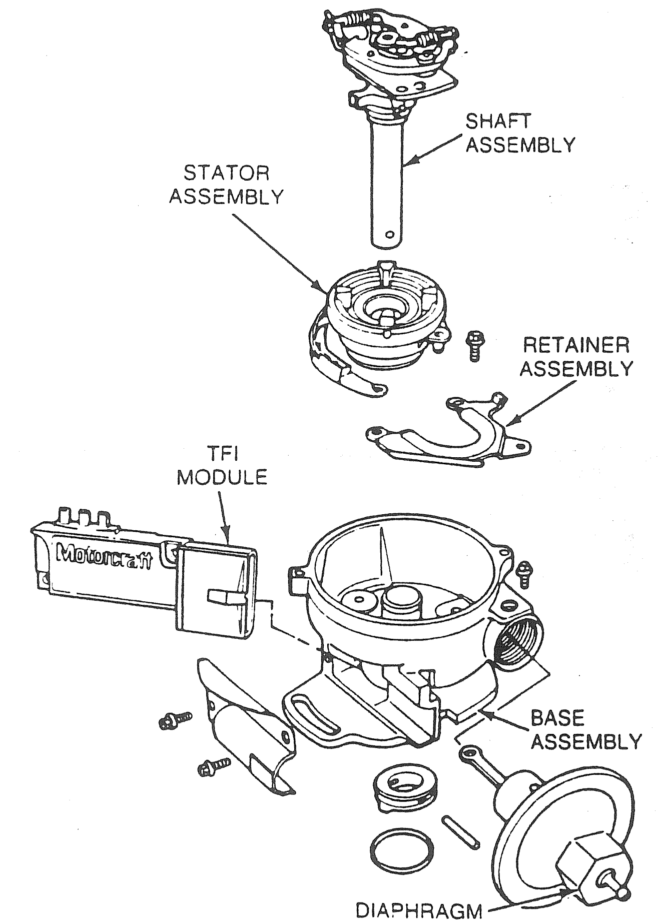
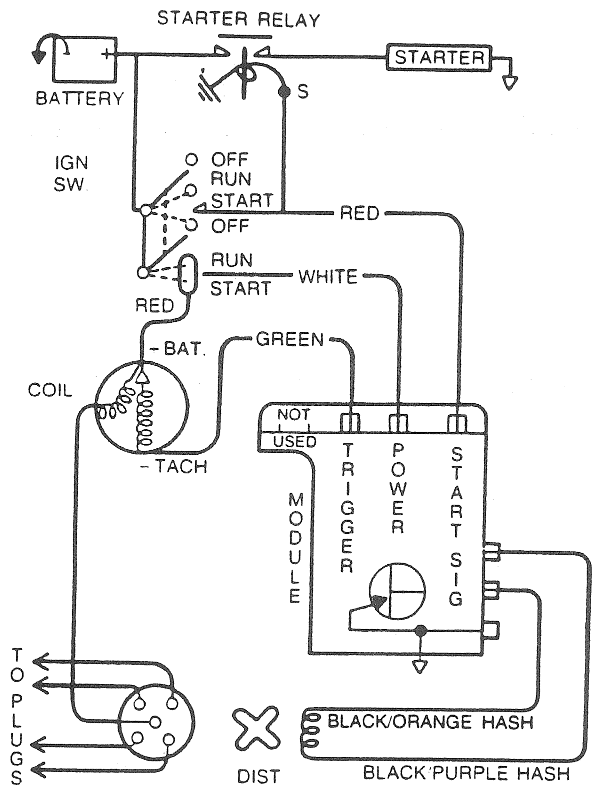


FIGURE 6–38
Exploded view of TFI-I distributor and module assembly. (Courtesy of Ford Motor Co.)



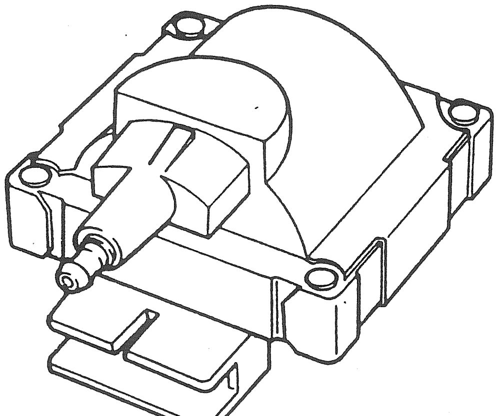


FIGURE 6–39
TFI-I, E-core coil. (Courtesy of Ford Motor Co.)

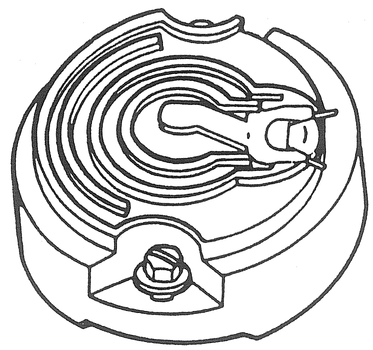


FIGURE 6-40
TFI-I, two-pronged rotor. (Courtesy of Ford Motor Co.)

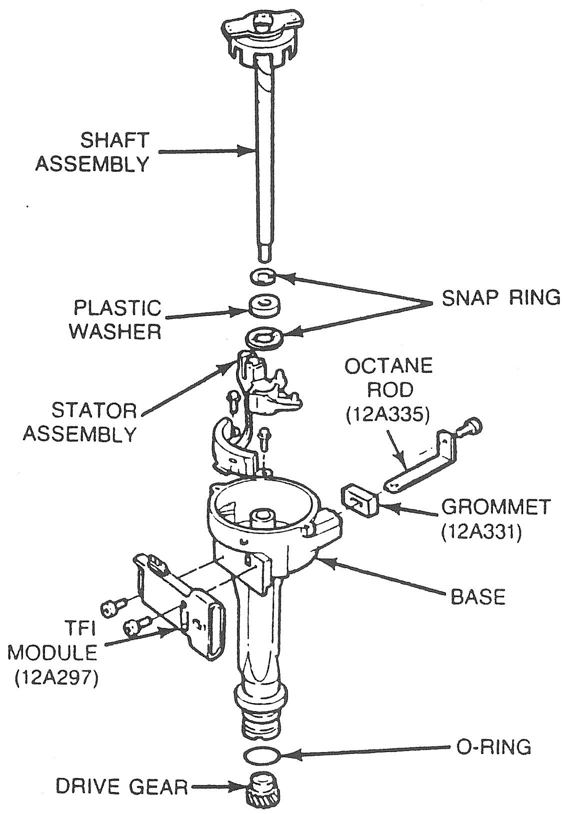


FIGURE 6-41
TFI-IV distributor. (Courtesy of Ford Motor Co.)

6-8 FORD TFI-IV IGNITION SYSTEM

In 1983, Ford introduced a TFI-IV ignition and the EEC-IV system. The TFI-IV module mounts onto the universal distributor in the same manner as in the TFI-I system (Fig. 6-41). A modification in the TFI-IV module circuitry provides for push-starting the vehicle.

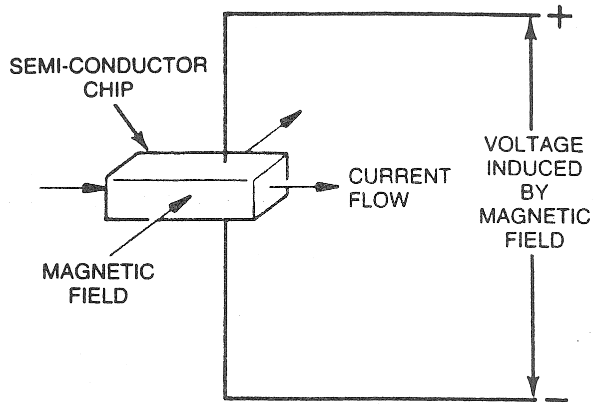


FIGURE 6-42
Hall effect. (Courtesy of Ford Motor Co.)

TFI-IV Distributor Design

The TFI-IV universal distributor, unlike its TFI-I counterpart, contains no advance mechanisms (Fig. 6-41). Therefore, all adjustment of ignition timing and dwell are accomplished electronically. The system uses the E coil and TFI-I rotor and cap to distribute the high voltage to the spark plugs. Also, the universal distributor is adjustable for resetting base timing, if required.

This distributor also has an *octane rod.* The rod provides a method of adjusting for differences in fuel octane ratings. The adjustment is accomplished by replacing the standard zero degree rod located in the distributor bowl by either a three- or six-degree retard service replacement rod.

In place of a pickup coil, the TFI-IV distributor has a *profile ignition pickup (PIP) sensor.* The PIP sensor consists of a special armature and a Hall-effect switch. The armature, made of ferrous material, attaches to the end of the distributor shaft. The armature has a certain number of windows and metal tabs or shutters, the number of which depends on the engine. For example, a four-cylinder engine has four windows and four tabs, while a V-8 engine will have eight of each. In either case, these windows and tabs rotate past the stator assembly whenever the distributor shaft turns.

The stator assembly contains a Hall-effect switch. The *Hall-effect switch* consists of a semiconductor chip on one side and a magnet on the other. The semiconductor chip has a small but constant input voltage applied to it (Fig. 6-42).

Edward Hall, in 1879, discovered the principle upon which this sensor operates. Simply speaking, Hall discovered he could generate a small voltage in

a semiconductor material by passing a small constant current through it in one direction, while at the same time, directing the magnetic field from the magnet across the chip at a right angle to the flow of current.

The force of this field produces an output voltage (called Hall voltage) across the semiconductor, as shown. If the current flow through the chip is from left to right, the voltage produced in the semiconductor will be on its upper and lower edges.

The movement of a tab or shutter between the magnet and the chip creates a shunt, or alternate path, for its magnetic field (Fig. 6-43). This changes the magnetic field strength through the semiconductor and causes the chip's output Hall voltage to vary.

When a TFI-I armature window enters the area between the magnet and the chip, the magnetic field begins to pass through the chip as indicated by the left illustration in Fig. 6-44. As the magnetic field enters the semiconductor, it produces a positive Hall voltage on the chip edges, which is used to close the primary coil circuit. The voltage increases to maximum as the window fully opens for magnetic pathway through the chip.

Notice in this illustration that the switch is off during this time. The reason for this switch designation is that the positive voltage has turned off the operation of the secondary ignition circuit.

As a tab begins to come between the semiconductor and the magnet, its magnetic lines of force are shunted back to the magnet. Since fewer lines of force are cutting the semiconductor, its voltage drops rapidly and the Hall switch turns on the secondary ignition circuit. With the switch on, the zero

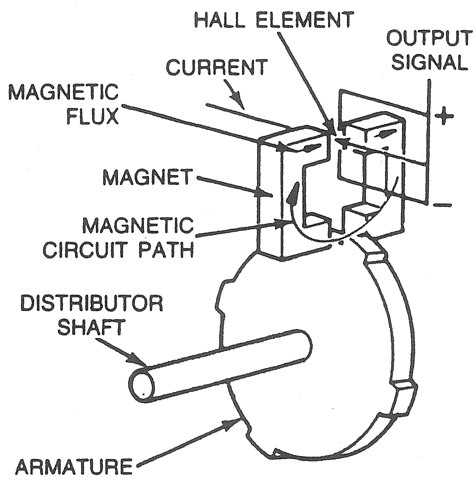


FIGURE 6-43
Effect of armature on the magentic field. (Courtesy of Ford Motor Co.)

Hall voltage triggers the opening of the primary circuit. The voltage remains at positive zero during the period that the tab completely blocks the air gap between the chip and the magnet.

Although the Hall sensor requires a connection for input voltage to the chip, its output voltage does not depend on the speed of the rotating armature. Therefore, the sensor generates a full-strength Hall voltage even at slow cranking speeds.

Moreover, the Hall switch, as it turns off and on, produces a pulsating DC sine wave signal with sharp corners that looks similar to a square wave. The signal is known as the *PIP signal* and is an indication of both crankshaft position and speed. The PIP signal is fed to both the TFI-IV module and the ECA (Fig. 6-45).

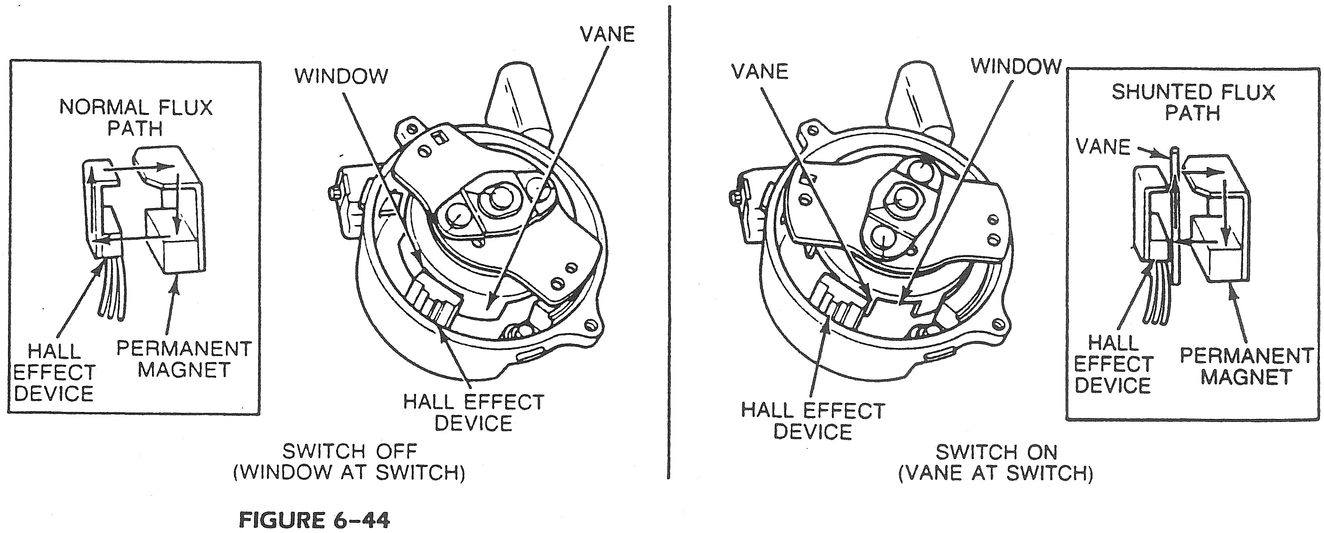


FIGURE 6-44
Hall-effect switch operation in a TFI-IV distributor. (Courtesy of Ford Motor Co.)

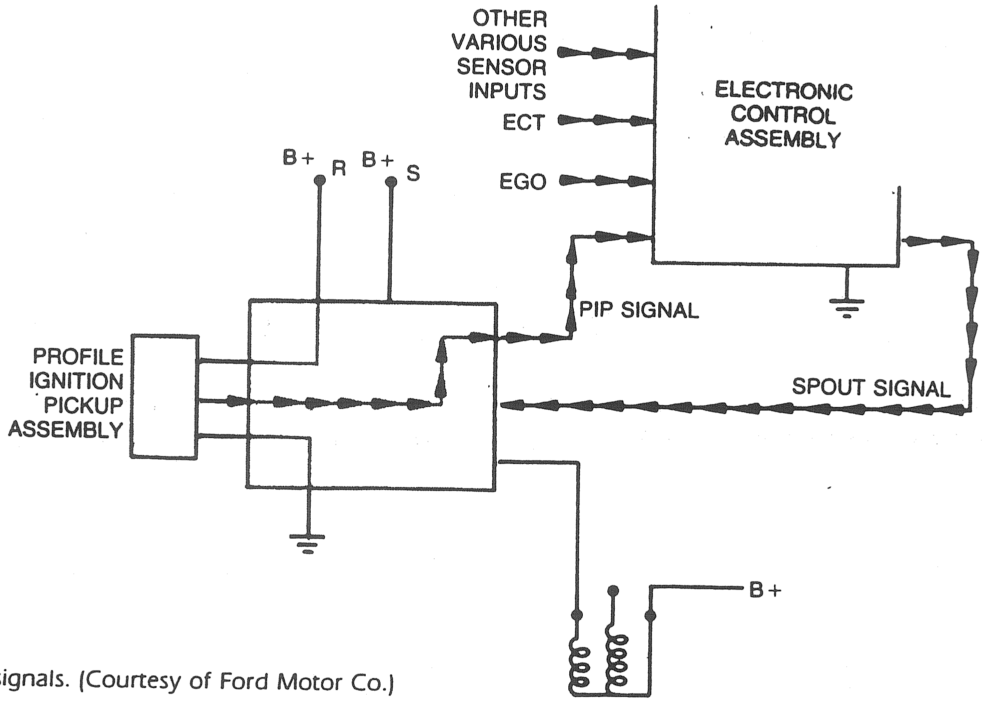


FIGURE 6-45
PIP and SPOUT signals. (Courtesy of Ford Motor Co.)

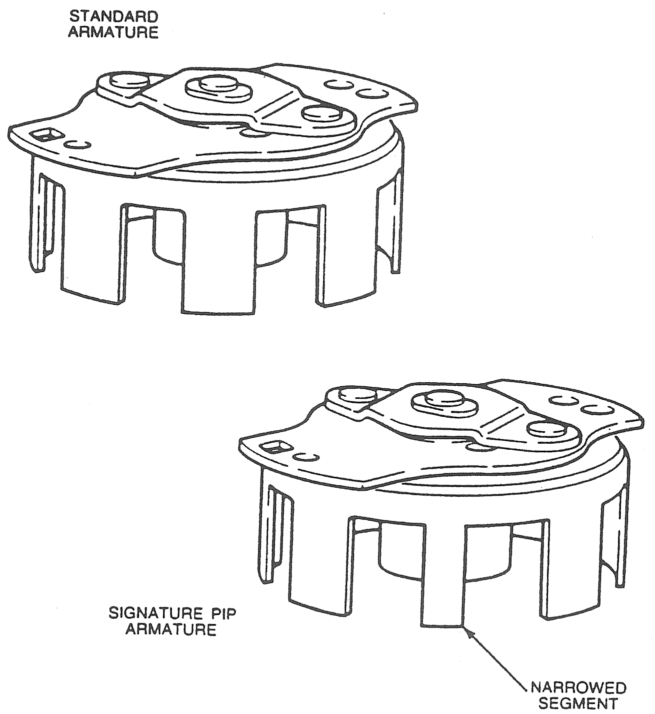


FIGURE 6-46
Signature PIP armature. (Courtesy of Ford Motor Co.)

The PIP signal is just one of the many inputs processed by the ECA. The ECA, after monitoring all sensor information, produces the *spark output (SPOUT)* signal. The SPOUT signal represents engine-operating conditions electronically, and it is sent back to the TFI-IV module for comparison with the PIP signal. The TFI-IV module then uses both of these signals to close and open the primary coil circuit at the correct timing intervals for all engine speeds and loads.

If the PIP signal is not generated by the Hall sensor, the engine cannot run because there will be no ignition. If the ECA has failed, or the PIP signal of a carbureted engine does not reach it, the engine will still run because the module can produce a base timing from the PIP signal. This is not the case in a fuel-injected engine because the ECA cannot operate the injectors without a PIP signal.

TFI-IV Modifications

The 5.0-liter sequential electronic fuel injection (SEFI) system incorporates a unique trigger armature for ignition/fuel synchronization. The ECA must be able to determine which PIP signal is for the number one cylinder. To accomplish this, one tab on the armature is narrower than the others, causing a different signal (Fig. 6-46). This is referred to as the *signature PIP signal.* The signal is necessry due to the need to energize each injector in relation to the engine firing order.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. Name the four negative characteristics of a contact point ignition system [6-1].
2. Why doesn't the TFI-IV distributor require any built-in advance mechanisms [6-8]?
3. What is the function of the contact points in a transistorized ignition system [6-2]?
4. TFI-I is similar to what other ignition system [6-7]?
5. What are the functional objectives of the SSI system [6-3]?
6. How does the Duraspark III system advance ignition timing [6-6]?
7. What is the main functional difference between the Duraspark I and II systems [6-4]?
8. Which Duraspark system utilizes the SSI coil [6-5]?

REVIEW

1. What produces the Hall voltage in the TFI-IV distributor [6-8]?
   a. inducing a voltage in the pickup coil
   b. passing a magnetic field through a current-carrying semiconductor chip
   c. passing current through the pickup coil in one direction
   d. passing current through the pickup coil in both directions
2. What is the name used to describe the difference between required and available voltage [6-1]?
   a. coil potential
   b. voltage reserve
   c. current reserve
   d. voltage potential
3. Where is the PIP sensor located [6-8]?
   a. in the TFI-IV distributor
   b. on the front of the engine
   c. on the rear of the engine
   d. in the microcomputer
4. What is the term used to describe the reduction in ignition system voltage at high speed [6-1]?
   a. voltage decay
   b. voltage reduction
   c. voltage variation
   d. potential loss
5. Which ignition system uses an E coil [6-7]?
   a. the Duraspark II system
   b. the SSI system
   c. both a and b
   d. neither a nor b
6. What part directly controls the primary current flow in the transistorized ignition system [6-2]?
   a. switching transistor
   b. contact points
   c. condenser
   d. zener diode
7. Where is the TFI-I system module located [6-7]?
   a. on the distributor
   b. on the left fender panel
   c. in the microcomputer
   d. in the coil assembly
8. What is the expected life of a contact point in a transistorized ignition system [6-2]?
   a. 5,000 miles
   b. 10,000 miles
   c. 15,000 miles
   d. over 20,000 miles
9. The pulse ring of a Duraspark III system is installed to create a reference timing of how many degrees [6-6]?
   a. 20 degrees
   b. 10 degrees
   c. 5 degrees
   d. 0 degrees or TDC
10. At what point does the spark plug fire [6-3]?
    a. when the magnetic pulse generator in the distributor produces a positive zero voltage
    b. when the magnetic pulse generator in the distributor produces a positive voltage
    c. either a or b
    d. neither a nor b

11. Which distributor cap uses male cable terminals?
    a. Duraspark I
    b. Duraspark II
    c. both a and b
    d. neither a nor b

12. The CP sensor is part of what system [6-6]?
    a. SSI system
    b. Duraspark I
    c. Duraspark II
    d. none of these

13. Which ignition system uses centrifugal and vacuum advance mechanisms [6-3]?
    a. Duraspark I
    b. SSI
    c. Duraspark II
    d. none of these

14. What system can use the universal ignition module [6-5]?
    a. Duraspark II
    b. Duraspark I
    c. SSI
    d. transistorized

15. The coil in which system has a special alignment lug [6-4]?
    a. SSI
    b. Duraspark II
    c. transistorized
    d. none of these

16. Dual-mode ignition modules are used on what system [6-5]?
    a. SSI
    b. Duraspark II
    c. Duraspark I
    d. transistorized

Chapter 7

TESTING TYPICAL FORD ELECTRONIC IGNITION SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will

- know the general precautions relating to testing electronic ignition systems.
- have a working knowledge in the use of test equipment on Ford electronic ignition systems.
- know where to locate Ford calibration codes.
- understand the use and importance of troubleshooting guides.
- be able to test a typical Ford solid state ignition (SSI) system.
- be able to test typical Ford Duraspark II and III systems.
- be able to test a typical Ford TFI-IV system.

Electronic ignition is one of the main operating systems of any engine. The gasoline power plant cannot function without it. Moreover, any malfunction in this system, no matter how small, affects not only engine performance but also the operation of other systems.

Most engineers consider electronic ignition the most important system for emission control and fuel economy on an engine. The number of ignition system modifications that have been made over the years, and the effects of component maladjustment or spark plug misfire on emissions and fuel economy support this view.

Therefore, if the engine is to operate properly, the electronic ignition system must work perfectly from the battery supply voltage at the ignition switch to the high voltage arc at the spark plugs. In other words, any problem that develops in either the primary or secondary circuit seriously affects performance, emission control, fuel economy, and driveability.

Over the years, Ford has produced quite a number of electronic ignition systems for various applications. Obviously, there is insufficient room in this chapter to thoroughly discuss the testing procedures for all of them. As an introduction to the process, this chapter will cover typical test procedures used on some of the systems covered in the last chapter. *Always follow the manufacturer's instructions, guides, and specifications when testing any of these system applications in order to prevent damage to the various components.*

7-1 GENERAL PRECAUTIONS, TEST EQUIPMENT, CALIBRATION CODES, AND TROUBLESHOOTING GUIDES

Before learning to test Ford systems, you must become familiar with a number of general precautions for working on electronic ignition systems, in general, and Ford systems, in particular. See the shaded box for these general precautions. Also, always observe the safety instructions covered in Chapter 5.

General Precautions

The precautions and instructions listed below will not only save you time in locating the actual cause of the problem but prevent the possible destruction of an otherwise serviceable component.

All Electronic Ignition Systems

1. The battery must be up to full charge in order to provide a test voltage. The charging system must also function correctly. If either the battery or the charging system is not operating properly, you may obtain incorrect test data, which will lead to the replacement of serviceable ignition components.

2. An alternator produces maximum or near maximum current flow if the battery does not hold a charge. When operating in this manner for long periods, the alternator can be damaged. Therefore, check the alternator for correct charging rate and its drive belt for specified tension before beginning ignition testing.

3. Always disconnect the negative (−) battery cable before changing any system components or removing and cleaning connections.

4. The correct parts must be used whenever replacing system components. Although many of the systems use devices that appear similar, many are not identical. Consequently, always check the catalog applications for the correct replacement part numbers.

5. Always adhere carefully to the manufacturer's instructions as to the use and care of test equipment. Make sure you are not using a piece of test equipment in a way not specified by its manufacturer. *Make certain that the test instruments you're using are compatible with the ignition system being tested (or spark control system, in the case of some Chryslers). If in doubt about whether to use a certain piece of equipment on a particular system, contact the equipment manufacturer or check the service manual of the vehicle.*

6. Before beginning any electrical testing, inspect all the connections throughout the system to make sure thay are clean and tight before checking voltages or continuity. Corroded or loose terminals may cause incorrect readings.

7. Turn off the ignition switch before unplugging the module or wiring harness connectors.

8. Do not test an engine with a catalytic converter for more than 30 seconds at a time with a spark plug not firing. This can damage the converter.

9. Always replace spark plug cables with ones equivalent to the originals.

10. Never puncture a spark plug or coil cable for any reason.

11. If a wire is punctured during a test, repair it with tape or some nonacetic RTV compound before placing the vehicle back in service.

12. The ohmmeter is used in a number of ignition system tests to confirm continuity of a circuit. To make this form of test, the meter is connected in parallel with the circuit or component being tested.

13. To determine if there is high resistance or there are corroded connections, use a voltmeter connected in parallel with the components or circuit to perform a voltage drop test.

14. Do not disconnect the battery terminals with the ignition switch on. The resulting high voltage surges can damage electronic components.

15. Do not disconnect or connect any electrical connections with the ignition switch on unless *specifically* directed to do so. Breaking or making an electrical connection can cause a high voltage surge that may damage electronic components.

Ford Systems

16. Always follow the emission label's specifications and test procedures.

17. Disconnect the ignition wiring harness connectors before conducting a compression test.

18. The ignition modules for the different systems are not interchangeable.

19. Whenever an ignition cable is removed from a spark plug, coil, or distributor, use silicone grease to coat its boot before reconnecting the wire.

20. All color codes referred to in the tests relate to stator pickup coil or module wiring. You must trace the wires back to these components for correct identification.

21. On the 1975–1976 SSI and the Duraspark I and II systems, while they are operating, do not remove the number one or number three spark plug cable from a four-cylinder engine, a number three or number five cable from an inline six-cylinder engine, the number one or number four cable from a V-6 engine, or the number one or number eight cable from a V-8 engine. The resulting high secondary voltage could arc to the stator pickup coil and damage it.

22. On 1979–1982 Duraspark and TFI-I systems, coat the brass rotor electrode surfaces on all sides with silicone grease to about ⅛-inch (3.17-mm) thickness. This is not necessary on the 1983 and later rotors, which have two-pronged electrodes. The grease is necessary to suppress radio noise or interference. The grease has no effect on the operation of the ignition or electronic engine control system.

Test Equipment

Various pieces of test equipment are necessary to check the various types of Ford electronic ignition systems. Having the proper test equipment available plays an important part in diagnosing and repairing the systems. Before you begin the ignition diagnostic procedures that follow, be sure you have an accurate analog volt-ohmmeter, power timing light with induction pickup, modified spark plug with the side electrode removed, 12-volt test light, several straight pins, and an ignition diagnostic test adapter (Fig. 7–1).

Larger pieces of equipment that are necessary include an engine analyzer or oscilloscope and a module tester. The scope will be used to test the operation of both the primary and secondary circuits. A unit that is especially helpful is the Allen "Smart" scope because it is capable of reading distributor pickup coil signals. The module tester electronically checks the serviceability of the ignition module either on or off the vehicle.

Figure 7–2 illustrates a spark tester. This device eliminates the use of a modified spark plug and a jumper lead while testing secondary voltage.

Lastly, you will need to prepare a number of jumper wires. Figure 7–3 shows the number of leads needed, their respective lengths, and the types of terminal ends required.

Calibration Codes

The 1981 and later emission control decals or the engine code label provide vehicle calibration and engine operating specifications (Fig. 7–4). From the de-

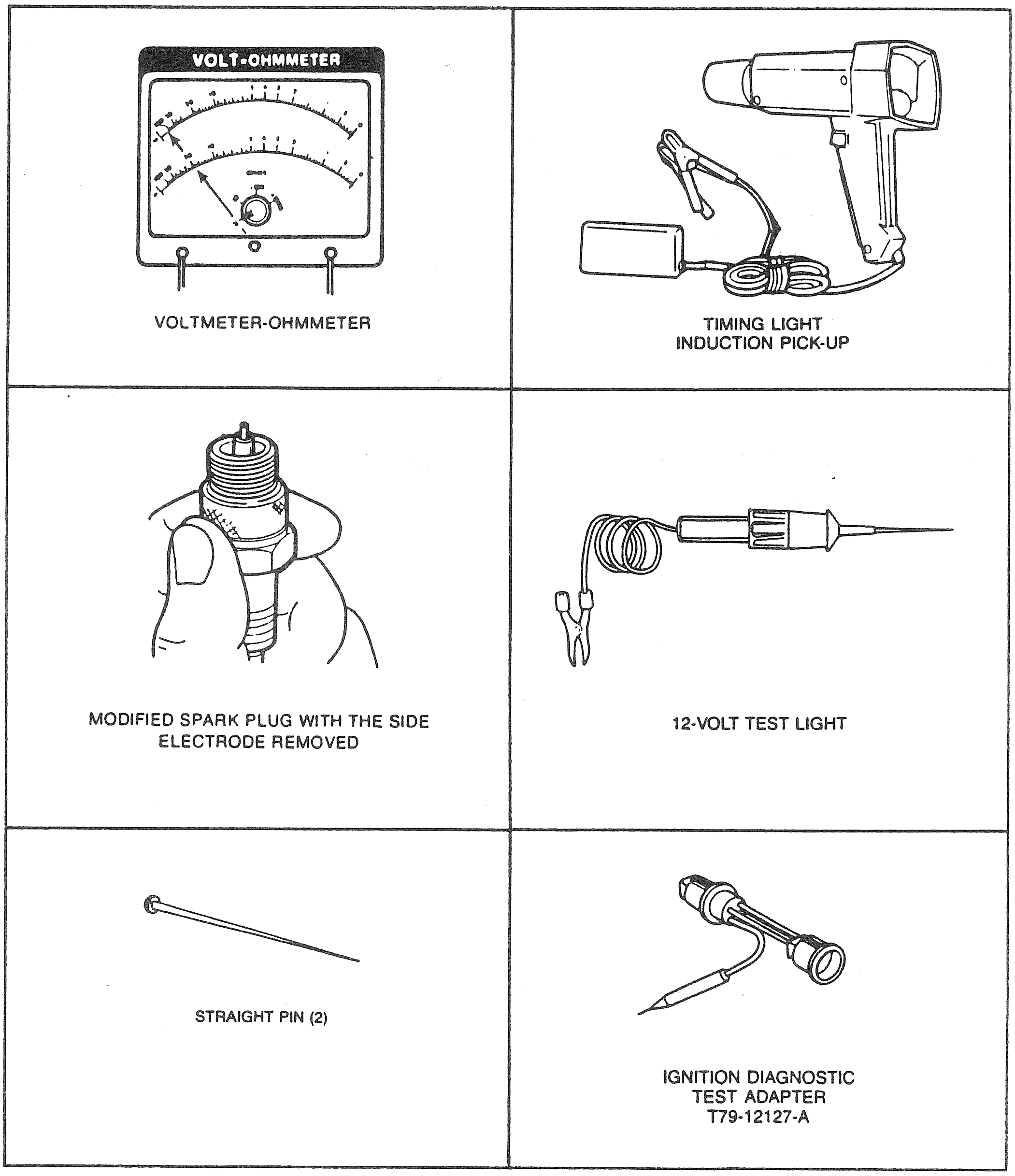


FIGURE 7-1
Diagnostic test equipment. (Courtesy of Ford Motor Co.)

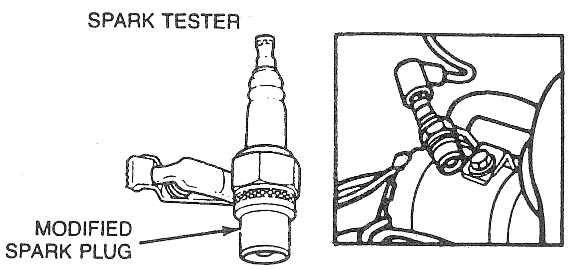


FIGURE 7-2
Spark tester. (Courtesy of Ford Motor Co.)

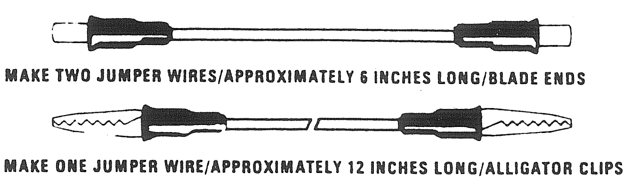


FIGURE 7-3
Preparation of jumper wires. (Courtesy of Ford Motor Co.)

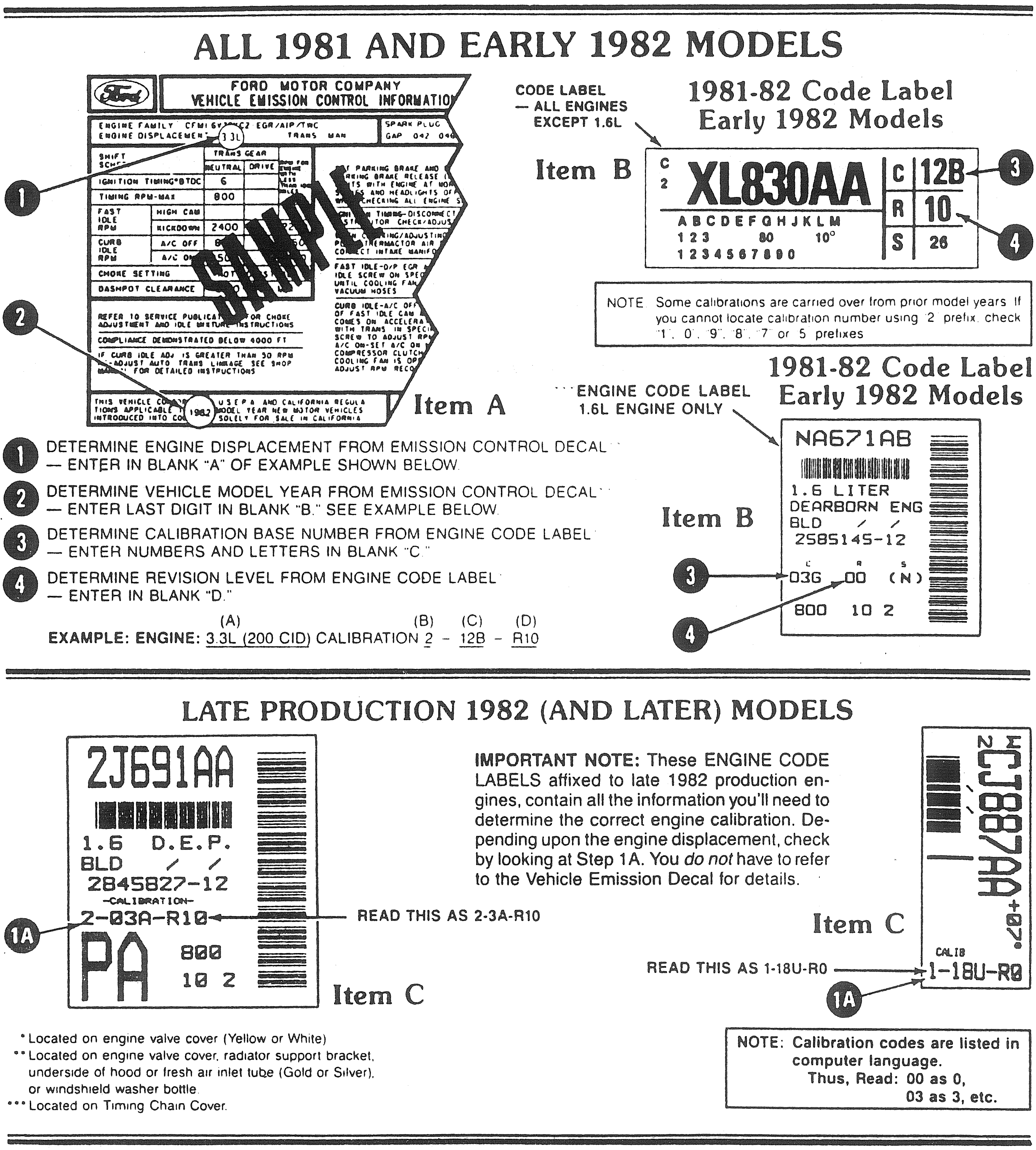


FIGURE 7-4
Vehicle engine and emission decals. (Courtesy of Ford Motor Co.)

cal and label, you can obtain the vehicle calibration code, which will provide the exact information regarding the ignition system installed on the vehicle being serviced.

To determine the calibration code on 1981 and early 1982 production engines, follow Steps 1-4, as shown in the illustration and described in Items A and B. To do this, look at the vehicle emission decal to determine Steps 1 and 2. For Steps 3 and 4, look at the engine code label for the additional information required. Then follow the instructions in Steps 1-4 that are shown in Fig. 7-4. For late 1982 and newer models, it is only necessary to examine the calibration code label, as shown in Item C, Step 1A.

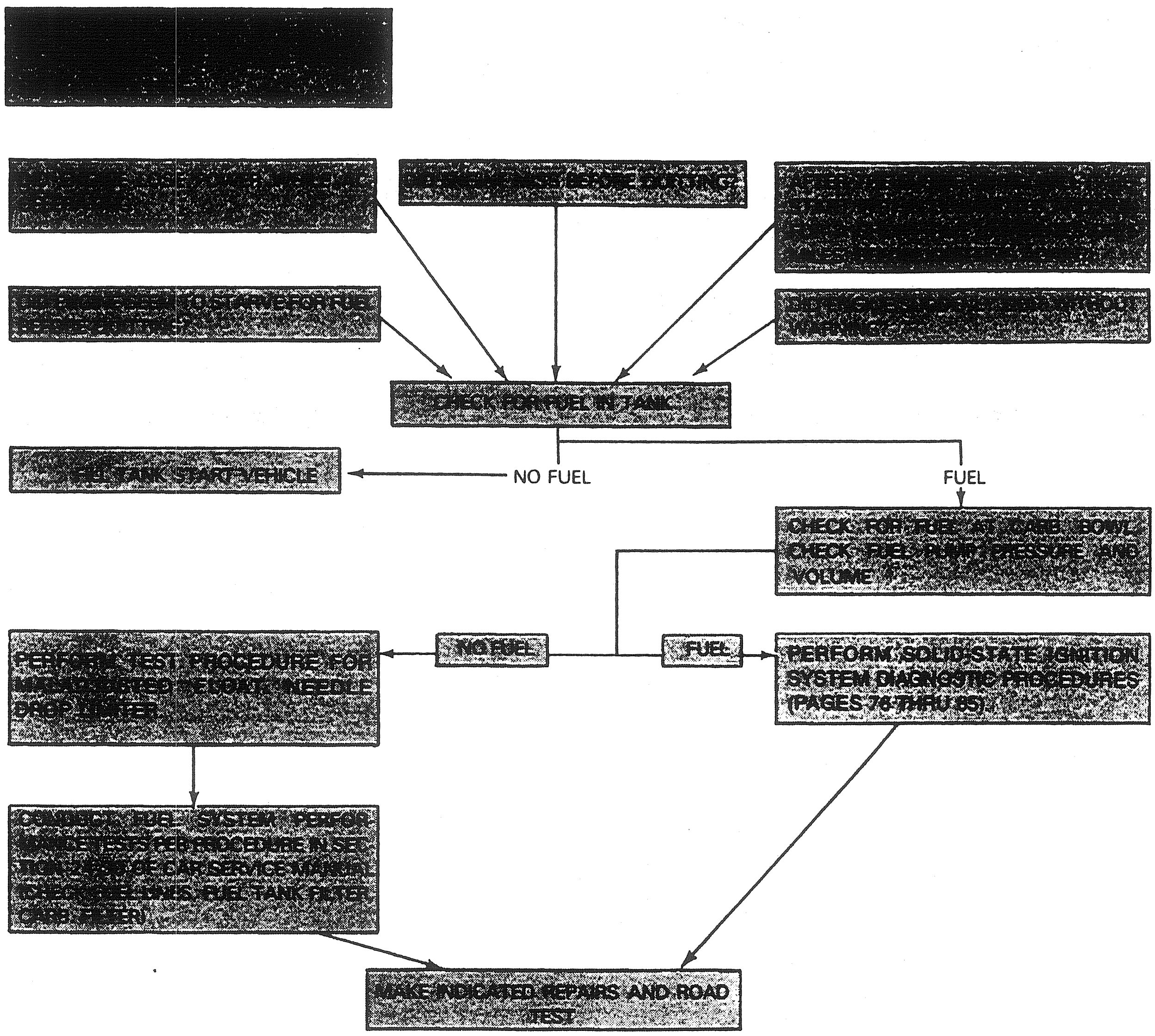


FIGURE 7-5
Typical troubleshooting guide. (Courtesy of Ford Motor Co.)

Troubleshooting Guides and Procedures

Ford and other vehicle manufacturers provide troubleshooting guides and procedures to assist the technician in locating the cause of a malfunction (Fig. 7-5). The guide shown in the illustration is for a poor but intermediate engine operating condition. First, the guide provides a number of customer questions that attempt to determine the events leading up to the problem. Next, the guide provides a number of items to check out in a given order.

It is extremely important that the technician follow the steps listed on the guide in the order shown. Also, the steps must always be performed no matter how insignificant they may appear. If these instructions are not followed, the technician will more than likely find that the parts replaced were not faulty and the driveability problem still remains. Obviously, this leads to a dissatisfied customer and extra work for the technician.

7-2 TESTING SSI AND DURASPARK II SYSTEMS

This section presents a troubleshooting procedure for typical solid state and Duraspark II ignition systems. The test procedure is divided into three parts: (1) engine cranks over normally but will not start, (2) engine operates but its performance is poor, and (3) engine starts up but fails to continue operating.

Engine Cranks Over Normally But Will Not Start

To locate the cause of the no-start condition, follow the steps outlined below.

1. Visually check the ignition system for any of the following defects:

   a. Disconnected spark plug cables.

   b. Insulation damage, or burned, overheated, loose, broken, or corroded conditions in wiring harnesses and connectors.

   c. Oil or moisture on the top surface area of the ignition coil or on the inner surfaces of the distributor cap. If moisture is present, remove it with a clean cloth. If there is an oil film on either part, remove it with alcohol and a clean cloth.

   d. Cracked or incorrectly installed distributor cap. If the cap is cracked, replace it, or install the cap correctly.

   e. If the engine still will not start, proceed to Step 2.

2. Check the ignition coil secondary voltage that is available during cranking by doing the following:

   a. Clamp the pickup lead of a scope to the coil high tension cable, following the manufacturer's instructions.

   b. Remove the coil wire from the distributor if a scope is not available and insert a modified spark plug or spark tester into its terminal boot (Fig. 7-6). Attach a spark tester to a good ground (see Fig. 7-2).

   c. Have an assistant crank the engine over with the ignition switch. Observe the scope screen for a vertical voltage trace; the voltage value is not important. Or check for spark at the modified plug or spark tester.

   d. If a strong spark is observed, the problem may be caused by the secondary ignition delivery system, or it may be a malfunction in the fuel system.

   e. If there was no evidence of a spark either on the scope screen or at the plug, use an ohmmeter to measure the resistance of the coil wire. Replace the cable if the resistance is not to specifications. Also, inspect the ignition coil for damage and carbon tracking. Replace the coil as necessary.

   f. If there is still no indication of a spark, proceed to Step 3.

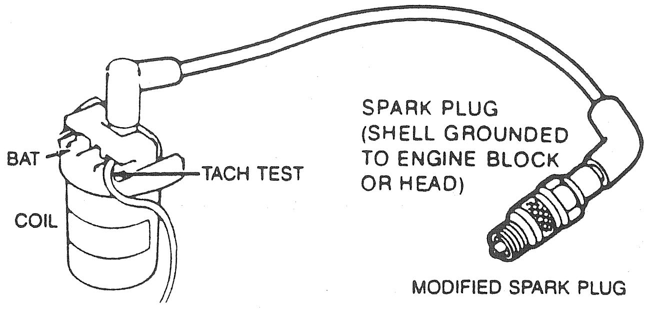


FIGURE 7-6
Secondary voltage check. (Courtesy of Ford Motor Co.)

3. Check for spark by tapping on the distributor (Fig. 7-7). To perform this test, do the following:

   a. Turn the ignition switch to the RUN position.

   b. Tap on the distributor with the plastic handle of a screwdriver.

   c. Check for the indication of a spark on the scope screen or at the modified plug. Tapping of the distributor should cause enough vibration to generate a strong enough voltage in the pickup coil to trigger a spark.

   d. If a good spark is observed each time you tap the distributor, the RUN circuit is op-

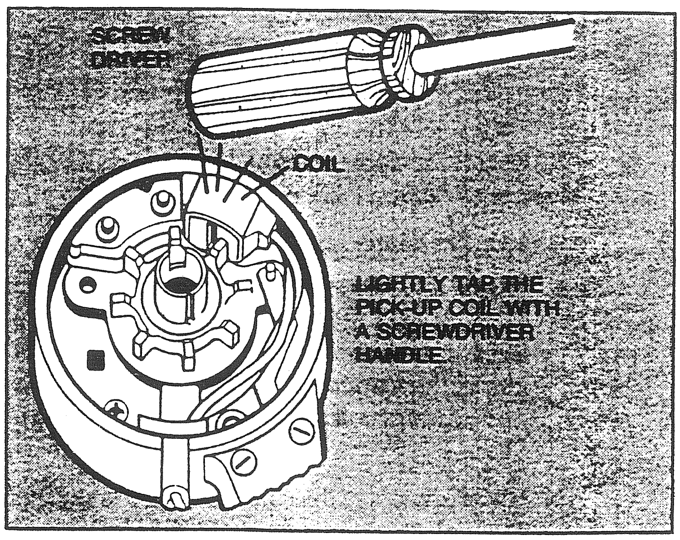


FIGURE 7-7
Testing for spark by tapping on the distributor. (Courtesy of Ford Motor Co.)

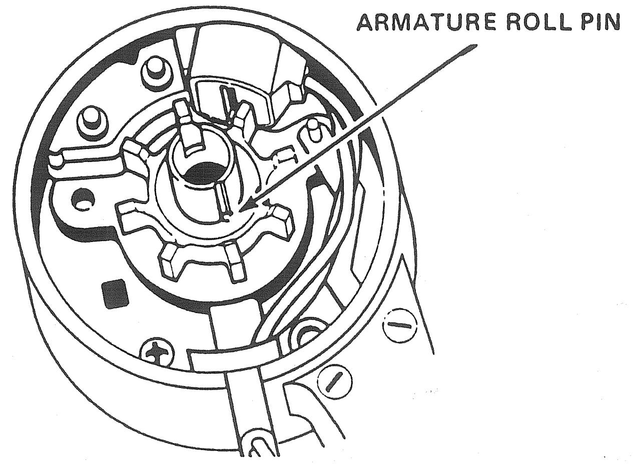


FIGURE 7-8
Checking the armature roll pin. (Courtesy of Ford Motor Co.)

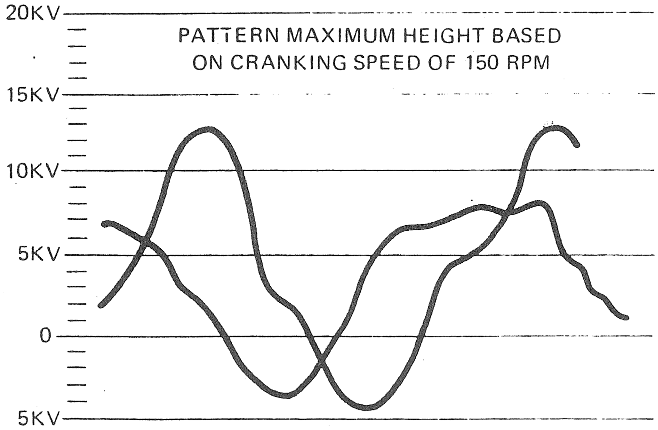


FIGURE 7-9
Testing pickup coil operation on a scope.

erating properly. In this case, proceed to Step 9.

e. If there is no spark indication, proceed to Step 4.

4. Check for proper rotor alignment. To perform this check, follow these instructions:

a. Remove the distributor cap.

b. Using a remote starter switch, crank the engine over until the timing marks are lined up exactly at the correct initial timing specification. Observe the motion of the armature while its engine is turning over.

c. If the armature does not rotate, the timing chain or gears may be broken, or the armature roll pin may be broken or not installed (Fig. 7-8).

d. If the roll pin installation was satisfactory and there is still no indication of a spark, proceed with Step 5.

5. Test the magnetic pickup within the distributor by using an Allen "Smart" scope on self-sweep operating mode.

a. Disconnect the pickup coil harness connector.

b. Connect the red test probe from the scope to the orange pickup wire.

c. Connect the black test probe to the purple pickup lead.

d. Place the ohm scale selector switch in the X10 position.

e. Crank the engine while observing the screen display.

f. The pattern in Fig. 7-9 is typical if the pickup coil is good. If the pattern is okay, move to Step 7.

g. If there is no pattern, proceed to Step 6.

6. Test the resistance within the stator pickup coil by doing the following:

a. Separate the ignition module four-wire connector. Inspect the connector for dirt, corrosion, and damage.

b. Using an ohmmeter, measure the pickup coil and harness resistance between the wiring harness terminals by mating with the orange and purple module wires (Fig. 7-10). Note: Wiggle the wires during the test.

c. If the resistance is to specifications, the pickup coil is serviceable.

d. If the resistance is not to specifications, replace the pickup coil.

e. Attach one ohmmeter lead to the distributor base.

f. With the other lead, alternately measure the resistance between the pickup coil wiring harness terminals by mating with the orange and purple module wires.

g. If the resistance between the two points is greater than 70,000 ohms, the harness is satisfactory. Proceed to Step 7.

h. If the resistance is less than 70,000 ohms, inspect the wiring harness between the

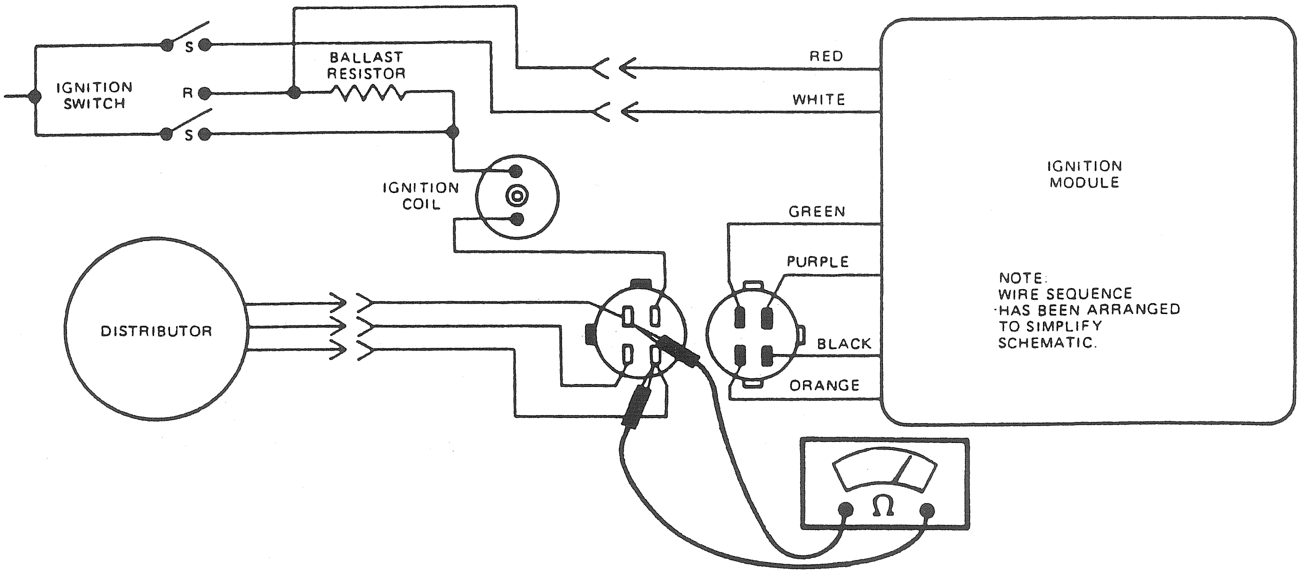


FIGURE 7-10
Checking pickup coil resistance. (Courtesy of Ford Motor Co.)

module connector and the distributor, including the distributor grommet.

i. Reconnect the four-wire connector.

7. Test the module voltage to see if it is 90 percent of battery voltage by doing the following:

a. Make sure the ignition switch is off.

b. Carefully insert a small straight pin in the red module wire (Fig. 7-11).

Caution: Do not permit the straight pin to contact an electrical ground.

c. Attach the negative (−) lead of the voltmeter to the base of the distributor.

d. With the voltmeter positive (+) lead, measure and record battery voltage.

e. With the voltmeter (+) lead, measure and record the voltage at the straight pin with the ignition switch in the RUN position.

f. Turn the ignition switch to the OFF position.

g. If the voltage is within 90 percent of that of the battery, proceed to Step 8.

h. If the voltage is less than 90 percent of battery voltage, inspect the wiring harness between the ignition module and the switch. Repair or replace the harness as necessary. If the wiring is okay, replace the ignition switch.

i. Remove the straight pin, and repair the puncture in the wire insulation.

8. Check the ballast resistor for the correct amount of resistance by doing the following:

a. Separate and inspect the ignition module two-wire connector with the red and white wires.

b. Disconnect and inspect the ignition coil connector.

c. Using an ohmmeter and jumper leads as necessary, measure the ballast resistance between the BATT terminal of the ignition coil connector and the wiring harness connector terminal with the red module wire (Fig. 7-12).

d. If the resistance is not to specifications, replace the ballast resistor.

e. If the resistance is to specifications, assemble all the connectors and proceed to Step 9.

9. Test the supply voltage to the ignition switch and the ignition module wiring harness to make sure it is within 90 percent of that supplied by the battery by doing the following:

a. Remove the modified spark plug or spark tester, and reconnect the coil high tension cable into the distributor cap.

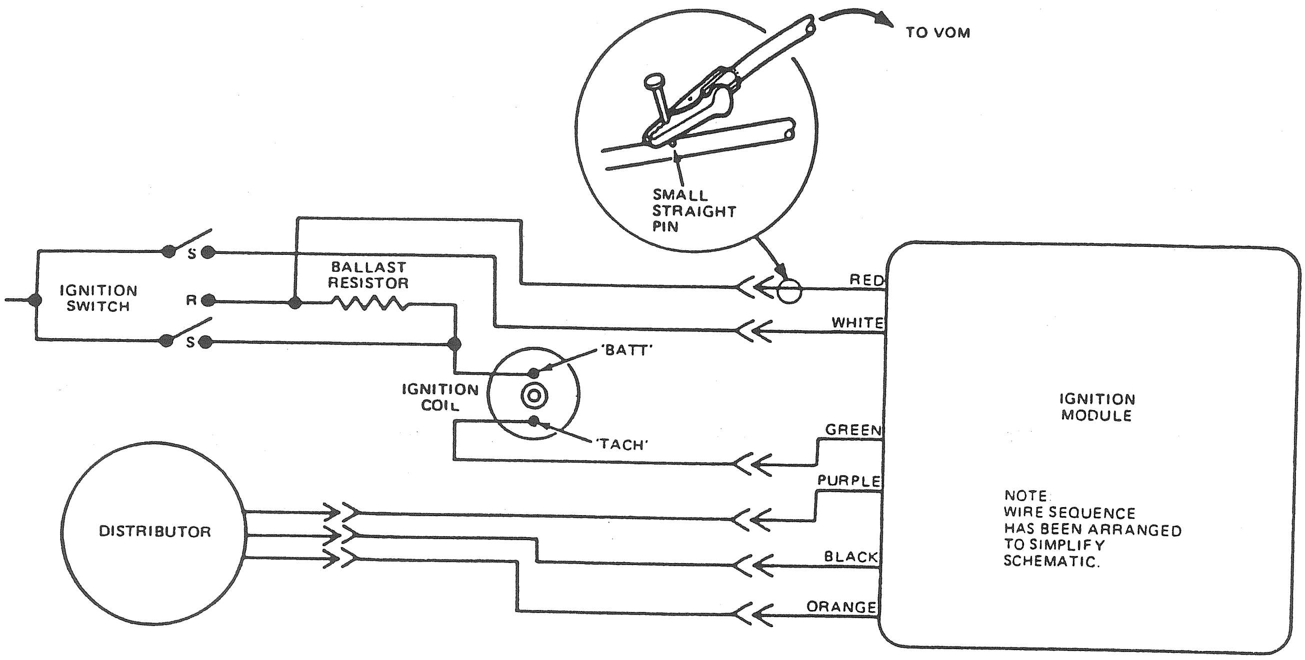


FIGURE 7-11
Testing module voltage. (Courtesy of Ford Motor Co.)

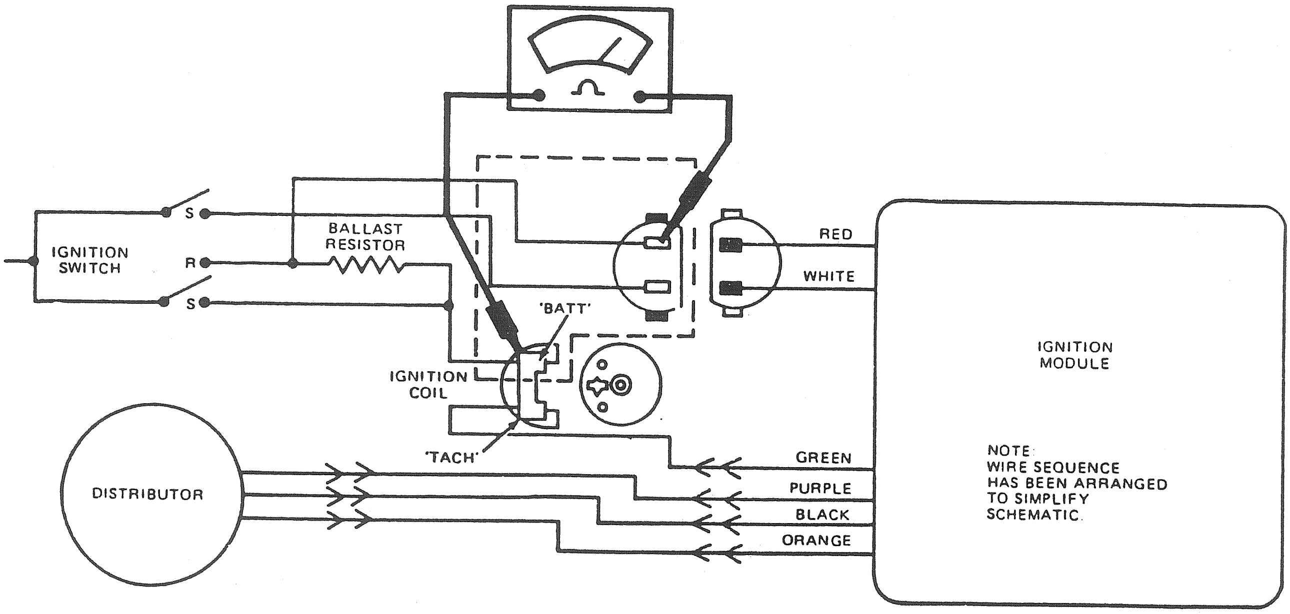


FIGURE 7-12
Ballast resistor check. (Courtesy of Ford Motor Co.)

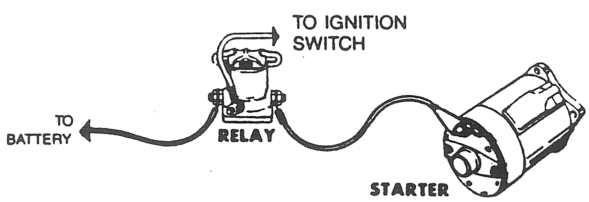


FIGURE 7-13
Starter relay terminals. (Courtesy of Ford Motor Co.)

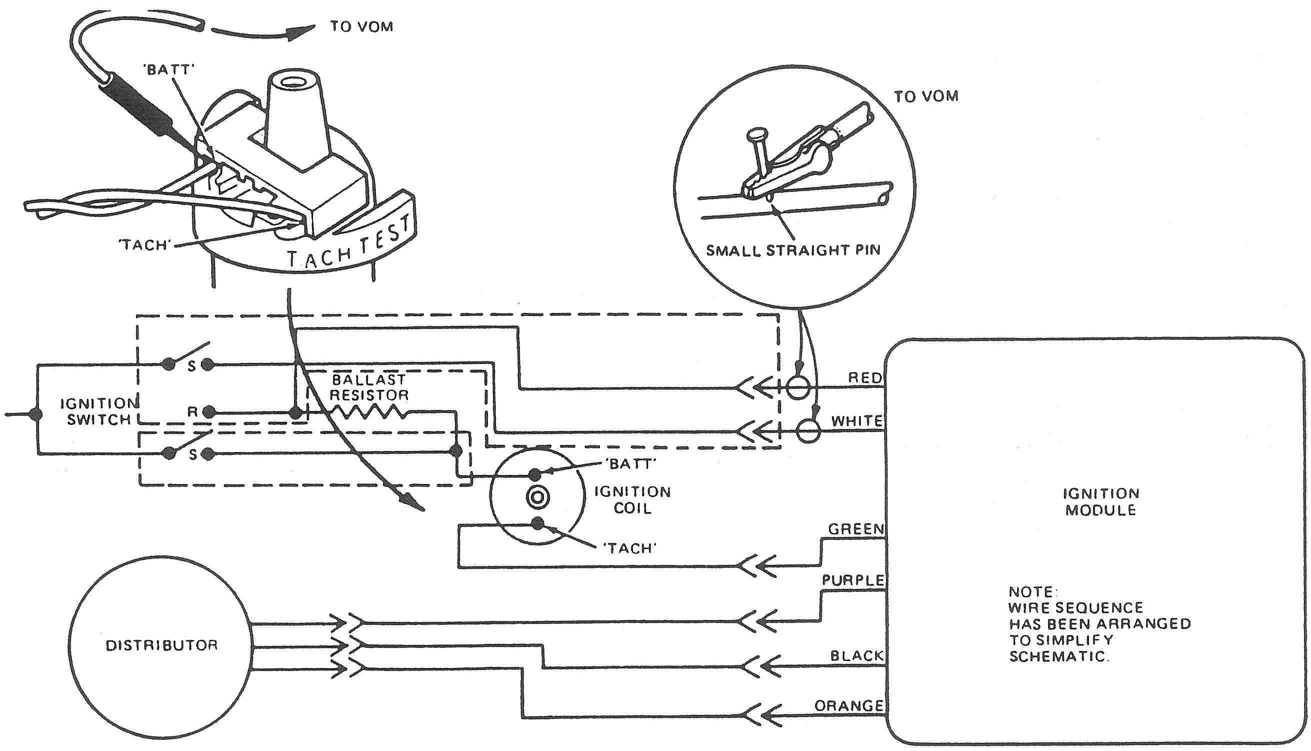


FIGURE 7-14
Checking supply voltage circuits. (Courtesy of Ford Motor Co.)

b. If the starter relay has an I terminal, disconnect the cable leading from the relay to the starter motor.

c. If the starter relay does not have the I terminal, disconnect the wire to its S terminal (Fig. 7-13).

d. Carefully insert small straight pins into the red and white module wires (Fig. 7-14).

Caution: Do not allow the straight pins to contact any electrical ground.

e. Using the voltmeter, measure and note the voltage at the battery.

f. Following the table in Fig. 7-15, use jumper leads and a voltmeter to measure the voltage at the points shown, with the ignition switch in the position indicated. Attach the voltmeter (−) lead to the distributor base. Also, wiggle the wires in the harness while making the tests.

g. After the test is complete, turn the ignition switch off.

h. If the measurements are not within 90 per-

CONNECT + VOM LEAD TO WIRE/TERMINAL	CIRCUIT	IGNITION SWITCH TEST POSITION
Red	Run	Run
White	Start	Start
"BATT" Terminal Ignition Coil	Ballast Resistor Bypass	Start

FIGURE 7-15
Supply voltage measuring points. (Courtesy of Ford Motor Co.)

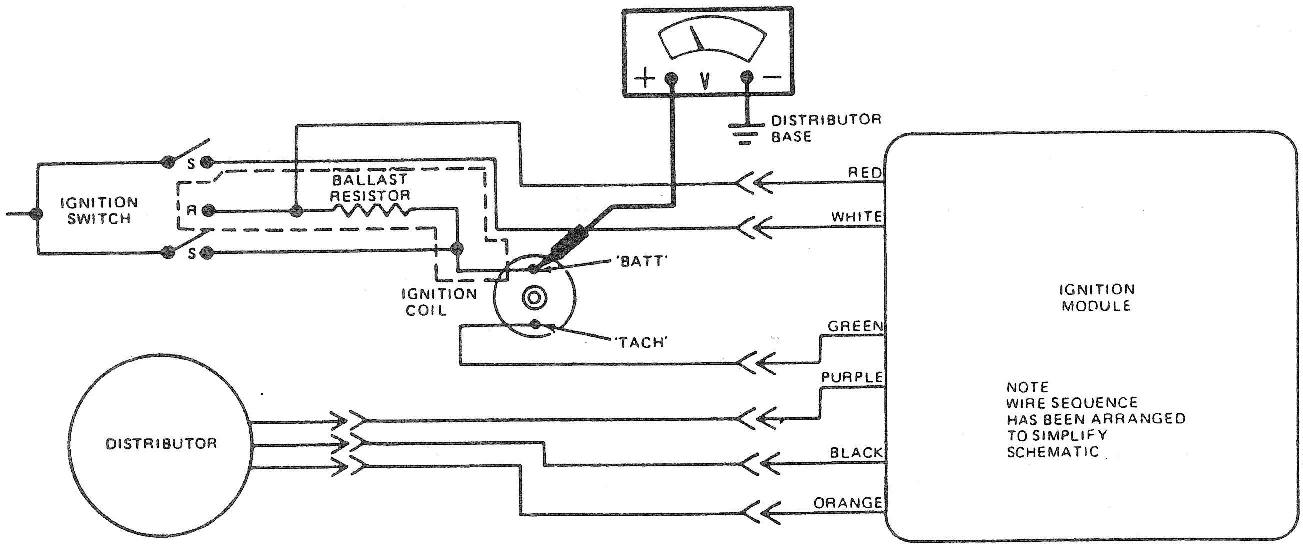


FIGURE 7-16
Testing coil supply voltage. (Courtesy of Ford Motor Co.)

cent of battery voltage, inspect the wiring harness, connectors, ignition switch, and the radio interference capacitor on the ignition coil. Repair or replace defective parts as necessary.

i. If the measurements are within 90 percent of battery voltage, supply voltage is satisfactory. Proceed to Step 10.

j. Remove the straight pins and repair the punctures in the wire insulation.

k. Reconnect the cable or wire removed from the starter relay.

10. Test the supply voltage to the ignition coil in the RUN mode by doing the following:

a. Connect the negative lead of the voltmeter to the base of the distributor (Fig. 7-16).

b. Turn the ignition switch to the RUN position.

c. With the voltmeter (+) lead, measure the voltage at the BATT terminal of the ignition coil.

d. If the voltage is between six volts and eight volts, the supply voltage is okay. Proceed to Step 11.

e. If the voltage is less than six volts or more than eight volts, proceed to Step 13.

11. Check the resistance in the coil's secondary windings by doing the following:

a. Disconnect and inspect the ignition coil connector and wires.

b. Connect the ohmmeter leads to the BATT and high voltage terminals of the coil (Fig. 7-17). Read the total resistance on the ohmmeter.

c. If the resistance is not to specifications, replace the ignition coil and reinstall its wiring connector.

d. If the resistance is to specifications, proceed to Step 12.

12. Test the resistance in the ignition coil primary windings by doing the following:

a. Disconnect the ignition coil wiring connector if you have not already done so.

b. Connect the ohmmeter leads to the coil BATT and TACH terminals (Fig. 7-18). Read the total resistance.

c. If the resistance is not to specifications, replace the coil, and reinstall its wiring connector.

d. If the resistance is to specifications, reinstall the wiring connector and proceed with Step 13.

13. Check the voltage drop across the primary circuit between the coil and the ignition module in the RUN mode by doing the following:

a. Carefully insert a small straight pin in the module's green wire (Fig. 7-19).

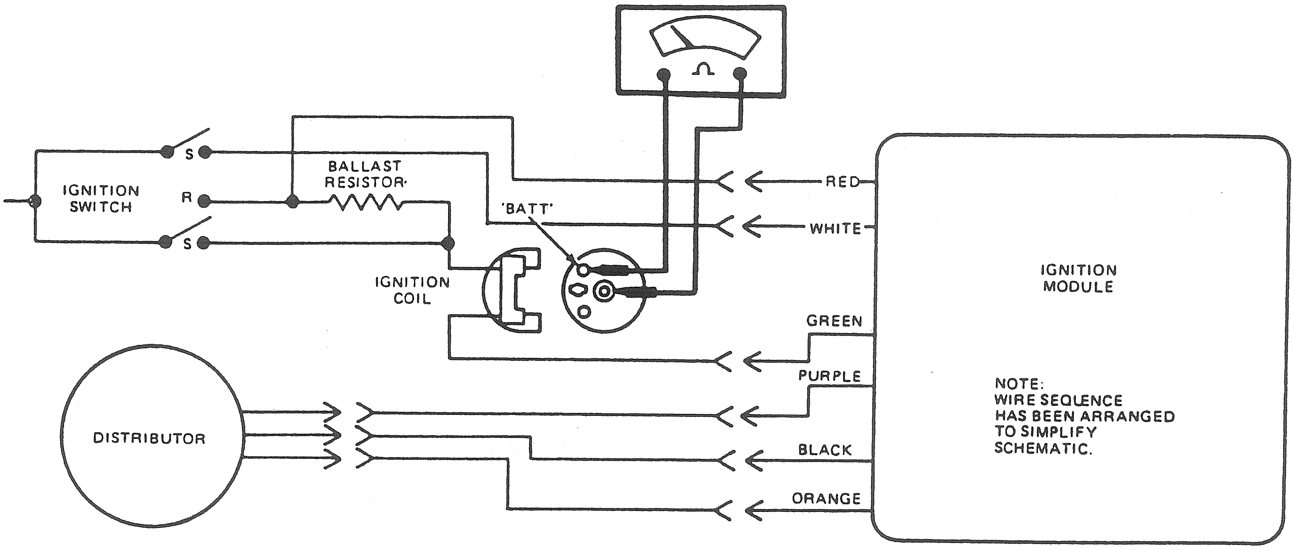


FIGURE 7-17
Checking secondary coil resistance. (Courtesy of Ford Motor Co.)

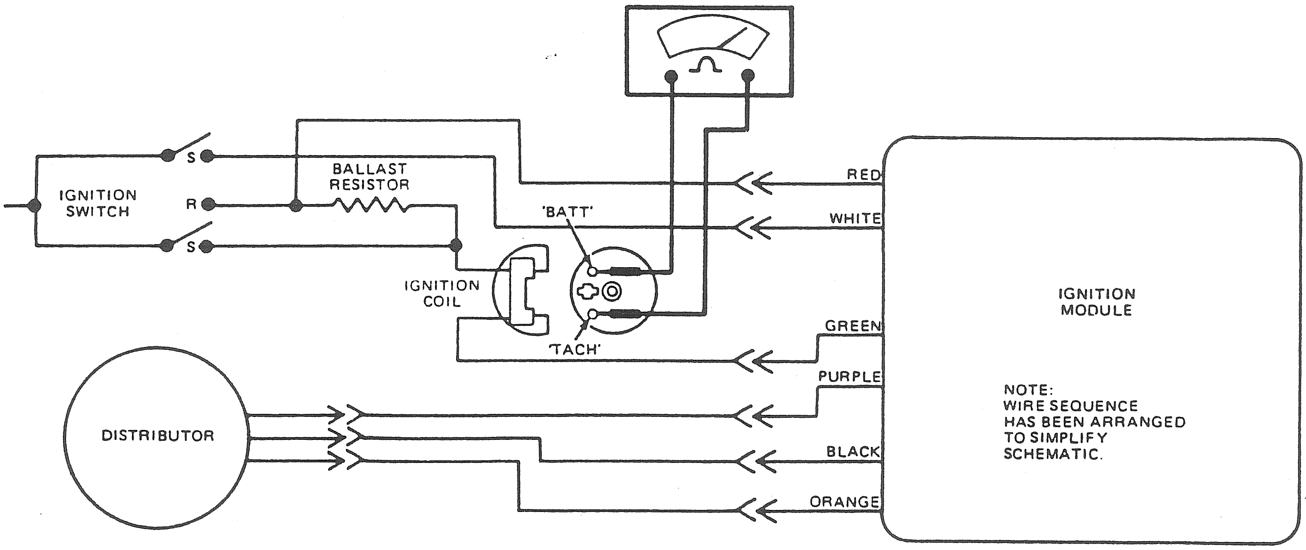


FIGURE 7-18
Testing primary coil resistance. (Courtesy of Ford Motor Co.)

Caution: *Do not permit the pin to contact an electrical ground.*

b. Attach the negative lead of the voltmeter to the base of the distributor.

c. Turn the ignition switch to the RUN position.

d. Connect the voltmeter positive (+) lead to the pin and measure the voltage.

e. Turn the ignition switch off.

f. If the voltage is greater than 1.5 volts, proceed to Step 14.

g. If the voltage is 1.5 volts or less, check the wiring harness between the ignition module and the coil.

h. Remove the straight pin and repair the wire insulation.

14. Test the distributor ground circuit for continuity by doing the following:

a. Separate the distributor connector from the harness. Inspect the connector for dirt, corrosion, and damage.

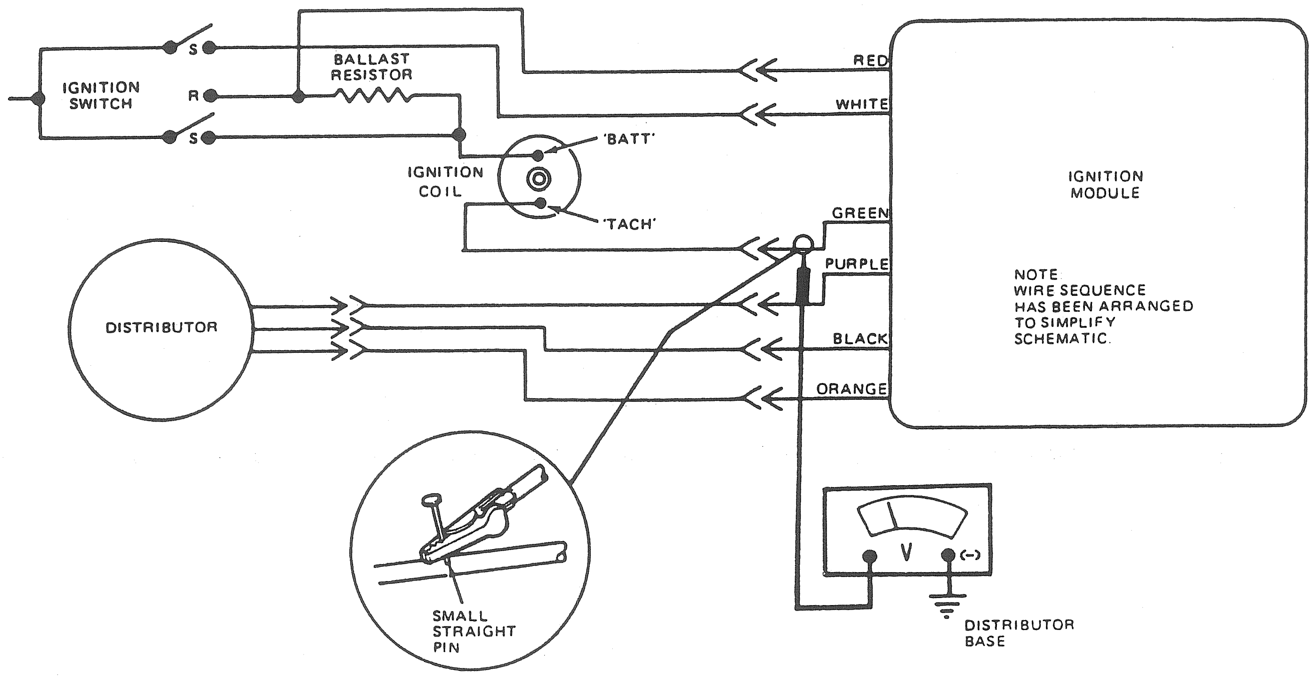


FIGURE 7-19
Primary circuit voltage drop test. (Courtesy of Ford Motor Co.)

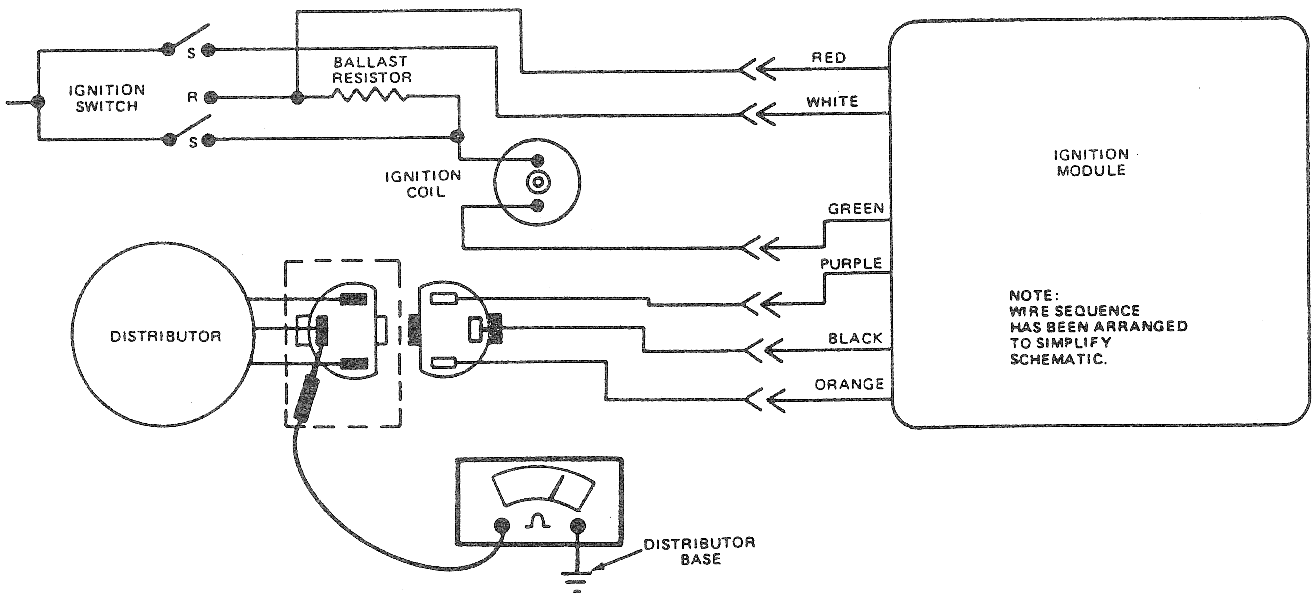


FIGURE 7-20
Distributor ground circuit continuity test. (Courtesy of Ford Motor Co.)

b. Attach one lead of the ohmmeter to the base of the distributor (Fig. 7-20).

c. Connect the other ohmmeter lead to the black wire in the distributor harness and read the resistance on the meter.

d. If the reading is one ohm or less, the continuity of the distributor ground circuit is okay.

e. If the resistance is greater than one ohm, check the ground screw in the distributor.

f. After the test is complete, assemble the distributor harness connector.

15. If none of the preceding steps has identified the problem, do the following to test the module:

a. Plug in a known good module at the harness connectors. Do not remove the old module at this point.

b. Perform a secondary voltage check as outlined earlier.

c. If the arc at the spark tester is satisfactory, the old module is defective and requires replacement.

d. Use an Echlin 4643 computerized module tester or its equivalent, if available, to check the original module. If the module fails the test procedure, replace it.

Engine Operates But Its Performance Is Poor

Poor performance of an engine may include such items as unsatisfactorily accelerating, detonating, misfiring, or stalling. These symptoms may just be an indication that the engine requires preventive maintenance, or they may be due to a malfunction resulting from wear on or failure of a component.

In any case, finding the cause of such a malfunction can require a considerable amount of testing. The following steps include methods of testing individual components as well as the entire system as a whole.

1. Check the ignition system visually for the following problems:

a. Disconnected spark plug cables.

b. Loose module and coil harness connectors.

c. Oil or moisture on the top surface of the ignition coil or on the inner surface of the distributor cap. If the coil or cap is wet, dry each with a clean shop towel. If there is an oil film, remove it with alcohol and a towel.

d. Cracked or incorrectly installed distributor cap. Replace the defective cap or attach it properly, as necessary.

e. Carbon tracking and burned electrodes inside of the cap and rotor. If any of these conditions are found, replace the defective component.

f. Incorrect installation of spark plug cables into the distributor cap sockets.

2. Check all vacuum hoses by doing the following:

a. Make sure the hoses are installed at the proper locations. Use a vehicle vacuum diagram as needed to check all hose routing.

Caution: *Vacuum hoses should never be disconnected in order to improve economy or performance. This may result in engine damage.*

b. If any vacuum hose is cracked or damaged, replace it.

3. Check ignition timing. To check initial or base timing and the operation of the centrifugal advance mechanisms, do the following:

a. Connect a power timing light or magnetic timing unit to the engine following the manufacturer's instructions.

b. Following the instructions on the emission decal, remove and plug vacuum line(s) as necessary. *Unplug the harness connector from the barometric or vacuum sensor on Duraspark II systems.*

c. Adjust curb idle speed to timing specifications. Make sure the engine is at normal operating temperature.

d. Read the base timing in the readout window or visually check it with a timing light (Fig. 7-21). It should be set dead-on to the specifications.

e. If the timing is off, loosen the distributor mount bolt. Next, turn the unit to align the marks on the damper and pointer, or until the correct amount of timing is shown in the readout window. Finally, securely tighten the distributor mount bolt.

f. Adjust engine speed to 2,000 rpm or the speed recommended for the engine.

g. Check the amount of advancement with the power timing light or by looking at the readout window.

h. If the timing advanced to specifications, the centrifugal unit is functioning correctly. If the timing advanced unevenly or not to the specified amount, check and repair the centrifugal mechanism.

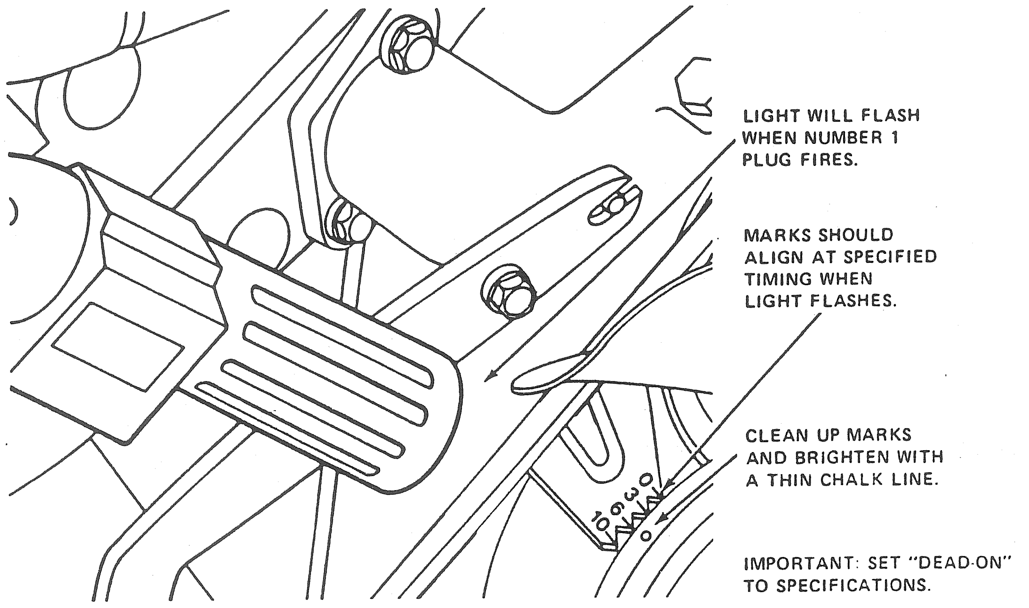


FIGURE 7-21
Checking ignition timing with a light. (Courtesy of Ford Motor Co.)

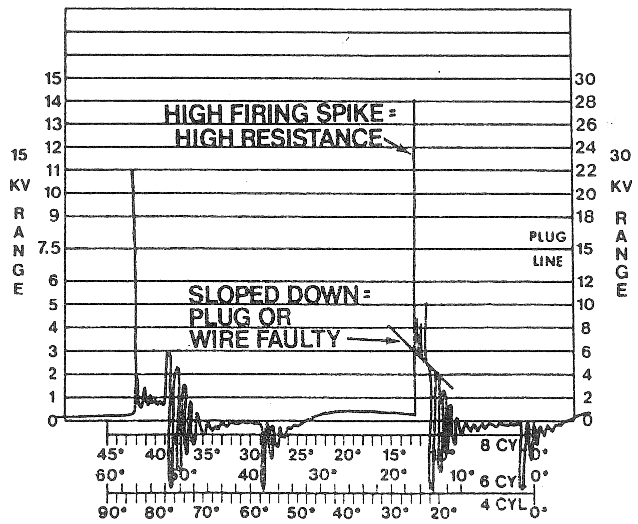


FIGURE 7-22
High resistance in a plug wire. (Courtesy of Ford Motor Co.)

i. Set the engine speed to 1,500 rpm to 2,000 rpm.

j. Connect and disconnect the hose to the vacuum advance while observing the readout window or timing marks.

k. The timing should advance and retard. If the timing does not change, the vacuum diaphragm may be defective or the breaker plate may be stuck. Check the diaphragm for serviceability with a vacuum pump. If the diaphragm is defective, replace it or repair the breaker plate as needed.

4. Scope test the secondary system by doing the following:

a. Connect the scope to the engine following manufacturer's instructions.

b. Adjust the idle to the speed recommended for the test or factory specifications.

c. Set the scope for an expanded parade pattern.

d. Check the pattern for high resistance in a spark plug or cable (Fig. 7-22). To determine if the problem is in the plug or cable, pull and ground the wire. If the high voltage spike drops, check and service the spark plug. If the spike remains high, check the cable and its connection at the distributor cap with an ohmmeter.

e. Check all the spark plug lines for evidence of high internal resistance (Fig. 7-23). If this pattern shows up at all speeds, the spark plug gap is too wide. If this condition changes with speed or load, it may be due to high compression, a lean air/fuel mixture, or a burned valve.

f. Inspect the pattern for signs of low firing voltage (Fig. 7-24). This may be the result of spark plugs that are shorted out, fouled, or gapped too narrow. Low compression or a grounded plug cable can also cause this

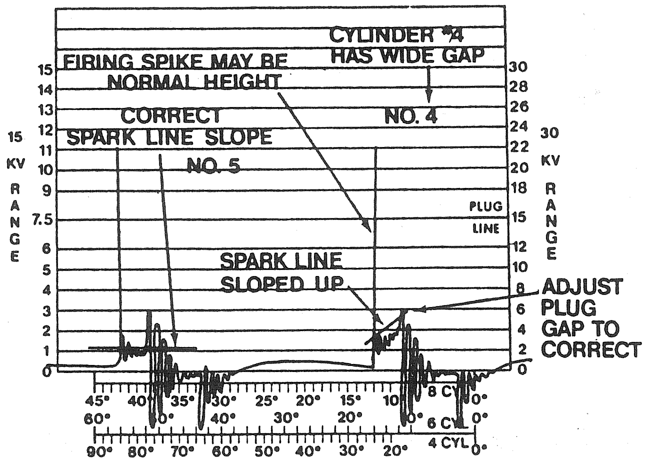


FIGURE 7-23
Plug spark line showing high internal resistance. (Courtesy of Ford Motor Co.)

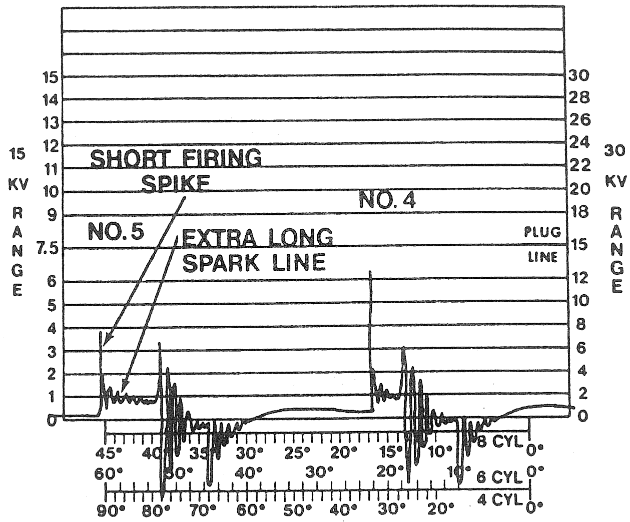


FIGURE 7-24
Low firing voltage. (Courtesy of Ford Motor Co.)

pattern. Check, service, replace, or regap the spark plug as necessary. If the spark plug is not at fault, check the cable or perform a compression test.

g. Check all the plug firing voltages under load. To do this, operate a vehicle with an automatic transmission in gear at 1,500 rpm with the brakes applied. If any firing line reaches within two-thirds of the coil's reserve voltage, replace the spark plug (Fig. 7-25).

h. Check the pattern for signs of cross firing or arcing in the cap (Fig. 7-26). If the bottom of the oscillation is lost intermittently, check the cap and rotor for cracks, carbon tracks, and scratches. Replace the defective part as necessary.

i. If all the firing lines indicate high resistance, test the rotor-air gap. To do this, remove a cable for one of the spark plugs and ground it (Fig. 7-27). If the voltage of the grounded plug is 8,000 volts or less, the air gap clearance is not excessive. If the voltage is over 8,000 volts, replace the rotor and repeat the test. If the voltage is still high, replace the distributor cap.

j. Set the scope display on raster and place a 250-watt heat lamp about one inch to two inches from the top surface of the module (Fig. 7-28). Apply the heat for about ten minutes, but do not permit the module temperature to exceed 212°F (100°C). Check the temperature of the module by applying a few drops of water to the module housing. Repeat the process every few minutes until the water drops just begin to boil; then remove the lamp. Next, start the engine and observe the scope pattern while lightly tapping on the module.

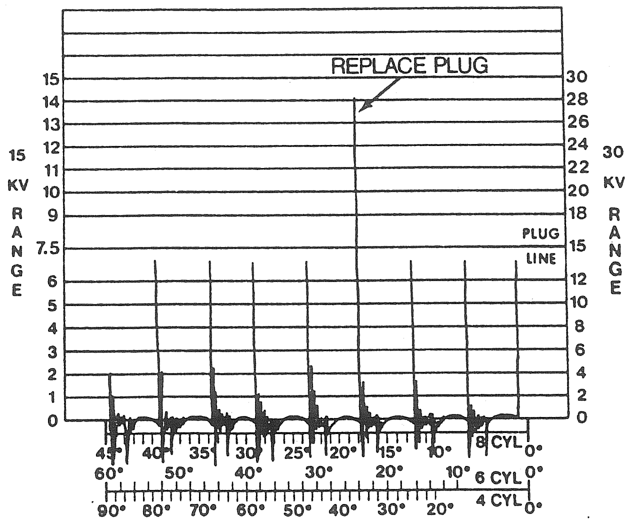


FIGURE 7-25
High firing line under load. (Courtesy of Ford Motor Co.)

Caution: Do not tap the module too hard; this may damage the unit. An erratic scope pattern while tapping the module indicates a defective unit.

k. The distributor pickup coil may be tested with a heat lamp in a similar manner as the module. Remove the distributor cap and dis-

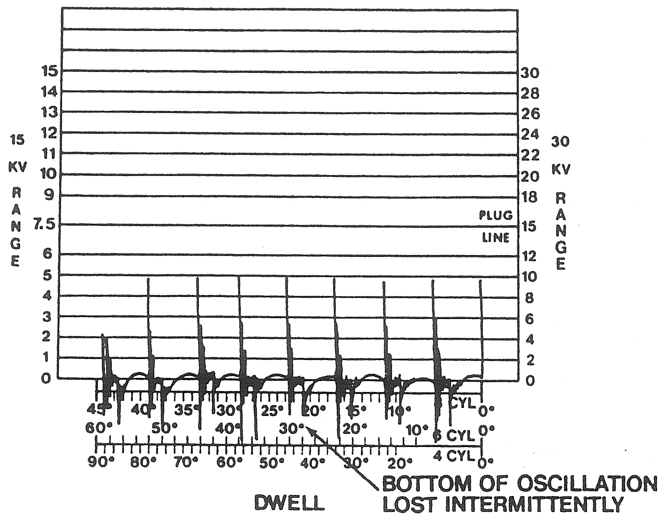


FIGURE 7-26
Cross firing or arcing in the distributor cap. (Courtesy of Ford Motor Co.)

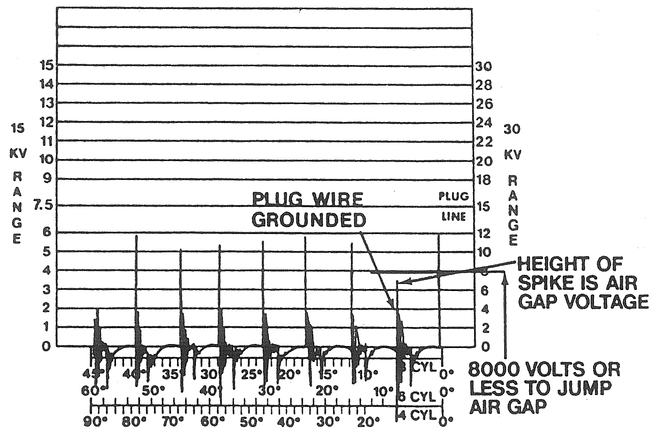


FIGURE 7-27
Rotor air gap test. (Courtesy of Ford Motor Co.)

connect the pickup coil harness connector. Connect the ohmmeter leads to the orange and purple wires. Tap the coil assembly very lightly with a screwdriver handle while watching the ohmmeter. The needle should remain steady in the specified range. Next, apply heat to the coil and watch the meter as you tap on the unit again. If the reading does not remain in the specified range, replace the coil. Connect one ohmmeter lead to the distributor base. Attach the other ohmmeter lead to first the orange and then the purple lead. Tap the coil while testing each lead and observe the ohmmeter. The meter needle should remain steady on infinity. If the coil does not pass this ground test while heated, replace it.

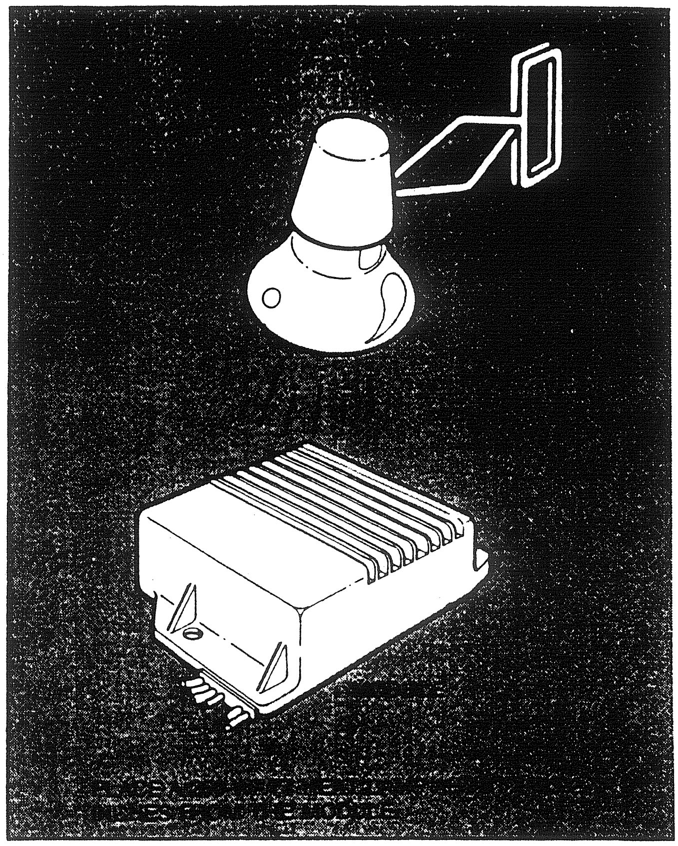


FIGURE 7-28
Heat testing a module. (Courtesy of Ford Motor Co.)

1. With the engine operating, attempt to recreate the problem by wiggling the wires at the coil, module, distributor, and all ignition harness connectors. While doing so, observe the raster scope pattern. If the pattern changes during the procedure, repair or replace the defective wire or connector.

Engine Starts But Fails to Continue Operating

In this situation, the engine will start but will stop when the key is released to the RUN position. This problem is usually the result of a fault in the voltage supply to the BATT terminal of the ignition coil. In this situation, check the ballast resistor and supply voltage by completing Steps 8 and 9 listed earlier in this section.

7-3 TESTING A FORD DURASPARK III IGNITION SYSTEM

There are many similarities in design as well as testing procedures between the Duraspark III and the systems presented in Section 7-2. One of the main differences is that the Duraspark III system uses a crankshaft position (CP) sensor in place of a pickup coil in the distributor. Consequently, there will be no pickup coil test procedures in this section. In addition, the distributor has no vacuum or centrifugal advance mechanisms because Duraspark III uses an electronic timing advance.

The secondary and timing tests for poor performance are almost the same for all systems. *Before testing a Duraspark III, always check the calibration code and use the specifications and instructions found on the emissions label.*

If an engine with a Duraspark III system cannot be started and operationally checked with a scope, perform the primary tests listed below to locate the cause of the problem.

Test 1—Run Circuits

The ignition module's run circuit can be easily checked by doing the following:

1. Separate the ignition module three-wire harness connector. Inspect the connector for dirt, corrosion, and damage.

2. Install the ignition diagnostic test adapter (Fig. 7-29).

3. Remove the coil high tension wire from the distributor and install it onto a modified plug and spark tester.

4. Turn the ignition switch to the RUN position.

5. Touch the diagnostic adapter lead to the battery positive (+) terminal. A spark should occur every time the lead touches the battery terminal.

6. Turn the ignition switch off.

7. If there was a spark, go to Test 2 of this section.

8. If there is no spark, proceed to Test 4.

Test 2—Start Circuits

Test the proper operation of the coil and its high tension cable by doing the following:

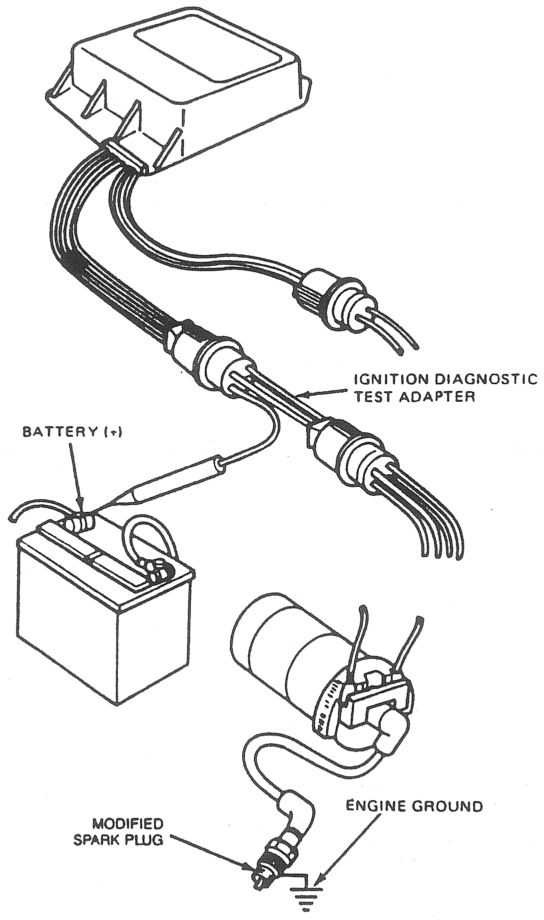


FIGURE 7-29
Testing the run circuits. (Courtesy of Ford Motor Co.)

1. Remove the diagnostic test adapter and assemble the ignition module connector.

2. While observing the spark tester, have an assistant crank the engine over with the ignition switch.

3. If sparks appear at the modified plug, inspect the distributor cap and rotor for cracks, carbon tracking, and silicone compound. Also, using the appropriate service manual, check for rotor alignment.

4. If there are no sparks at the plug, go to Step 3.

5. After completing the test, remove the spark tester and reconnect the coil wire to the distributor cap.

Test 3—Start Voltage

In this procedure, the ignition switch and the wiring harness to the module are checked to make certain

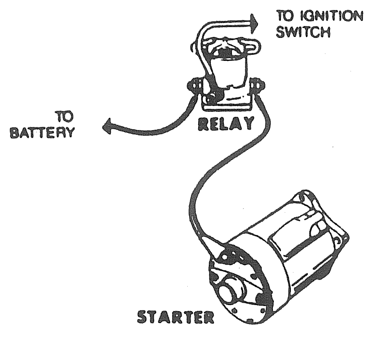


FIGURE 7-30
Terminal on the starter relay. (Courtesy of Ford Motor Co.)

the supply voltage is within 90 percent of that supplied by the battery. To perform this test, do the following:

1. If the starter relay has an I terminal, disconnect the cable between the relay and the starter motor.

2. If the starter relay does not have an I terminal, remove the wire from its S terminal (Fig. 7-30).

3. Carefully insert a small straight pin into the white module wire (Fig. 7-31). *Do not permit the pin to contact an electrical ground.*

4. Using the leads of a voltmeter, measure and note battery voltage.

5. Attach the negative (−) voltmeter lead to a good engine ground.

6. Using the table shown in Fig. 7-32 and the positive (+) voltmeter lead, measure the voltage at the straight pin with the ignition switch in the START position. Wiggle the wires in the harness during the test.

7. Turn the ignition switch off.

8. If the reading taken is less than 90 percent of battery voltage, inspect the wiring harness and connectors in the faulty circuit. If these are satisfactory, replace the ignition switch.

9. If the reading taken is at least 90 percent of battery voltage, inspect the wiring harness and connectors between the ignition and electronic engine control modules. If these are okay, proceed with Test 4.

10. Remove the straight pin and repair the wire insulation.

11. Reconnect the cable or wire removed from the starter relay.

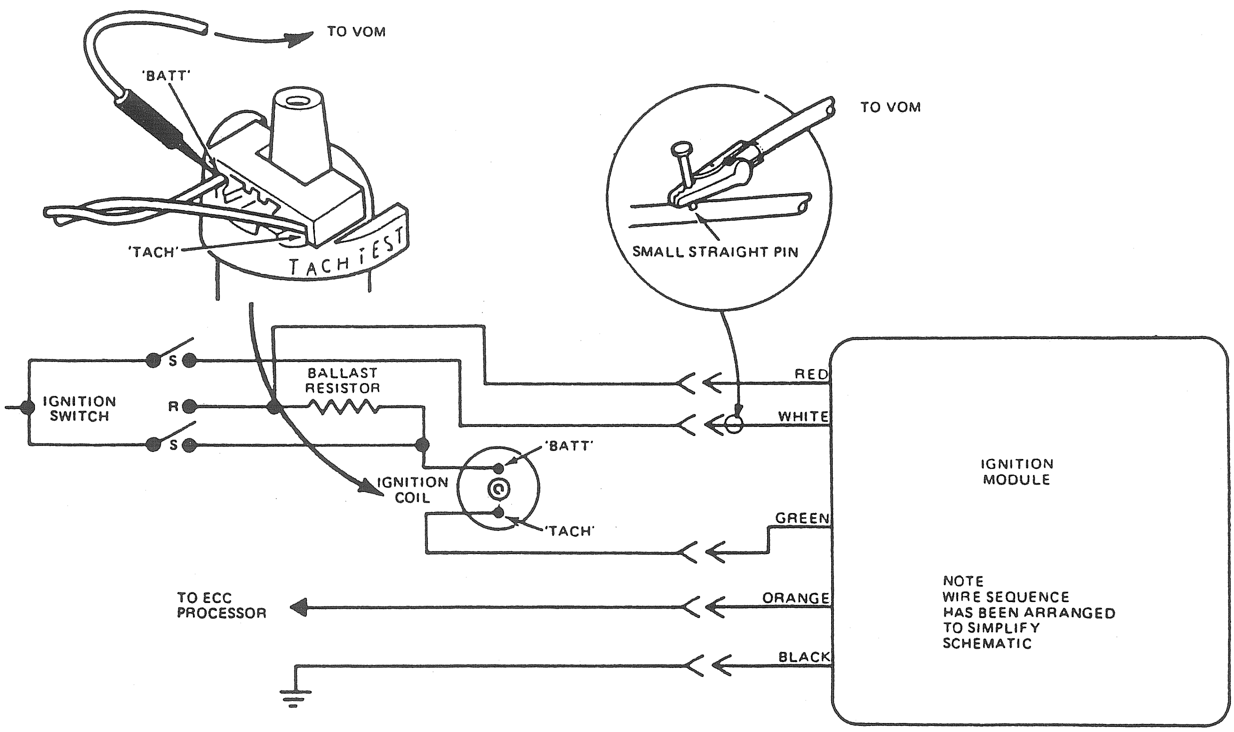


FIGURE 7-31
Checking start voltage. (Courtesy of Ford Motor Co.)

Test 4—Ignition Coil Primary Circuit Switching

Determine if the primary circuit of the ignition coil is properly switching by doing the following:

1. Attach 12-volt test light leads between the TACH terminal of the ignition coil and a good engine ground (Fig. 7-33).

2. Remove the module harness connector and install the diagnostic adapter.

3. Turn the ignition switch to the RUN position.

4. Touch the diagnostic adapter to the positive (+) battery terminal and then remove it several times. The test light should flash each time the adapter touches the battery terminal and is removed.

5. Turn the ignition switch off.

6. Remove the diagnostic adapter and test light; assemble the ignition switch module connector.

7. If the test light flashes, proceed to Test 5.

8. If the test light does not burn or is dim, go to Test 6.

CONNECT + VOM LEAD TO WIRE/TERMINAL	CIRCUIT	IGNITION SWITCH TEST POSITION
White	Start	Start
"BATT" Terminal Ignition Coil	Ballast Resistor Bypass	Start

FIGURE 7-32
Measuring points and switch positions from start voltage test. (Courtesy of Ford Motor Co.)

Test 5—Ignition Coil Secondary Resistance

To measure the resistance in the secondary coil windings, do the following:

1. Disconnect and inspect the ignition coil connector and the coil high tension cable.

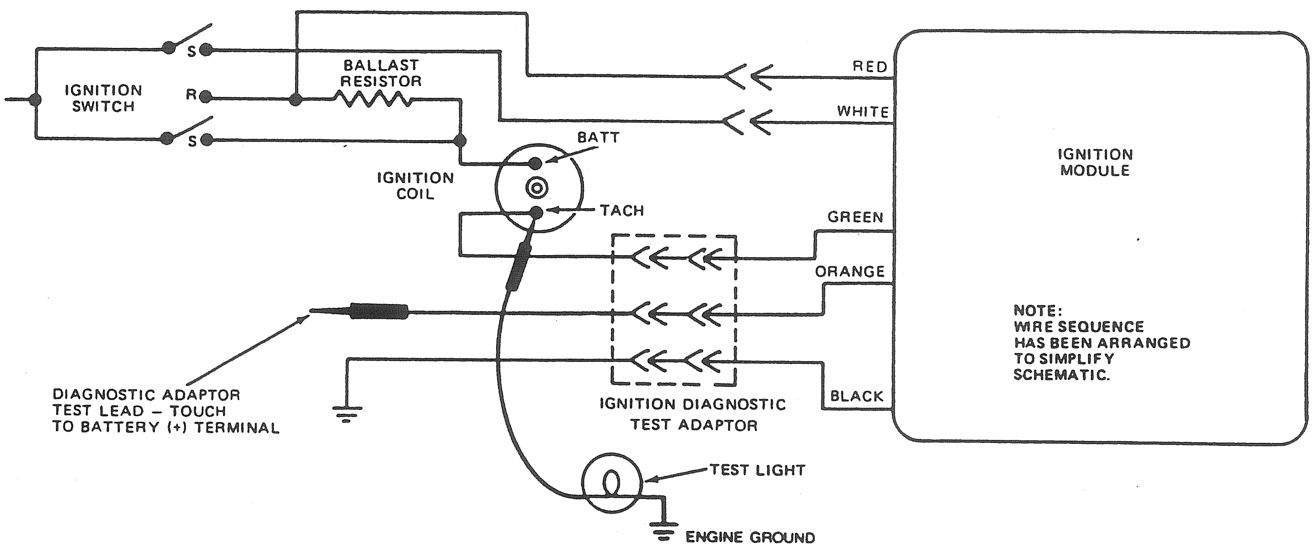
2. Using the ohmmeter leads, measure secondary resistance from the BATT to the high voltage terminals (Fig. 7-34).

3. If the resistance in the secondary windings is to specifications, check the coil high tension cable. If the resistance in it is greater than specifications, replace the cable. Also, check the ignition coil for damage or carbon tracking. If the coil checks out okay, proceed to Test 6.

4. If the coil's secondary resistance is not within specifications, replace the coil.

5. After the test is complete, install the ignition coil high voltage cable.

FIGURE 7-33
Testing the switching of the ignition coil primary circuit. (Courtesy of Ford Motor Co.)



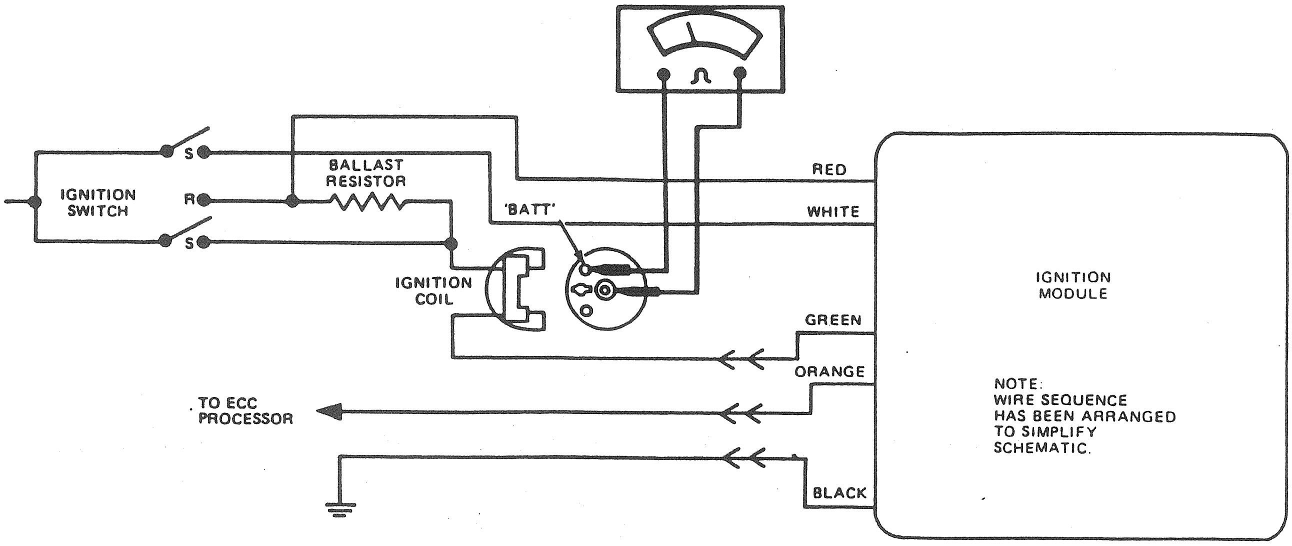


FIGURE 7-34
Measuring the resistance in the coil's secondary windings. (Courtesy of Ford Motor Co.)

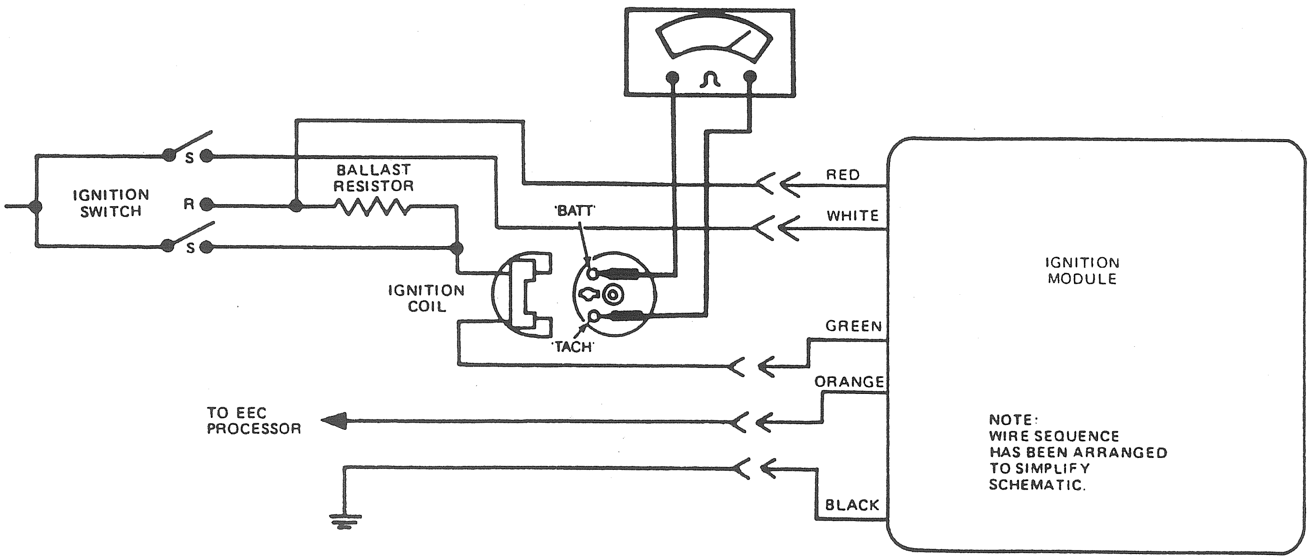


FIGURE 7-35
Measuring the resistance in the coil's primary windings. (Courtesy of Ford Motor Co.)

Test 6–Ignition Coil Primary Resistance

To measure the resistance in the primary windings of the coil, do the following:

1. Using the leads of the ohmmeter, measure the resistance from the BATT to TACH terminals of the coil (Fig. 7-35).

2. If the winding resistance is to specifications, proceed to Test 7.

3. If the resistance is less or more than specifications, replace the ignition coil.

4. After completing the test, install the ignition coil connector.

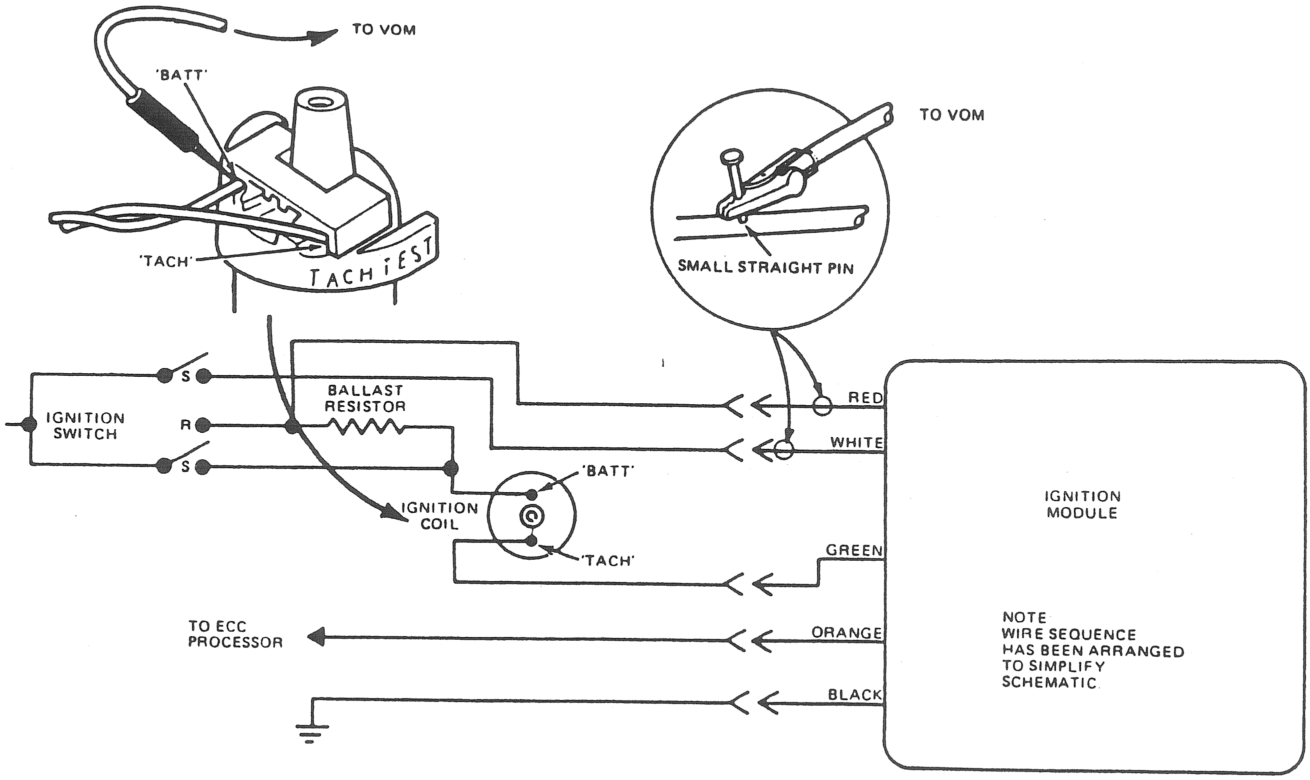


FIGURE 7-36
Checking the supply voltage circuits. (Courtesy of Ford Motor Co.)

Test 7—Run and Start Supply Voltage Circuits

The purpose of this test is to check the voltage in the run and start circuits. This procedure checks to make sure the ignition switch and wiring harness to the ignition module have a voltage supply that is within 90 percent of that provided by the battery during these two operating modes. To perform this test, do the following:

1. If the starter relay has an I terminal, disconnect the cable from between the relay and starter motor (see Fig. 7-30).

2. If the starter relay does not have the I terminal, remove the wire to its S terminal.

3. Carefully insert small straight pins into the red and white module wires (Fig. 7-36).

Caution: Do not permit the pins to contact an electrical ground.

4. With the voltmeter, measure and record battery voltage.

CONNECT + VOM LEAD TO WIRE/TERMINAL	CIRCUIT	IGNITION SWITCH TEST POSITION
Red	Run	Run
White	Start	Start
"BATT" Terminal Ignition Coil	Ballast Resistor Bypass	Start

FIGURE 7-37
Test points and switch positions for the voltage supply test. (Courtesy of Ford Motor Co.)

5. Attach the negative (−) voltmeter lead to the distributor base.

6. Using the table shown in Fig. 7-37 and the positive (+) voltmeter lead, check the voltage at the points indicated with the ignition switch in either the RUN or START position. Wiggle the wires in the harness while making the measurements.

7. Turn the ignition switch off.

8. If the voltage readings are less than 90 percent of battery voltage, inspect the wiring harness and connector(s) in the defective circuit(s). If these are okay, check the ignition switch. If the switch is satisfactory, replace the radio interference capacitor on the ignition coil.

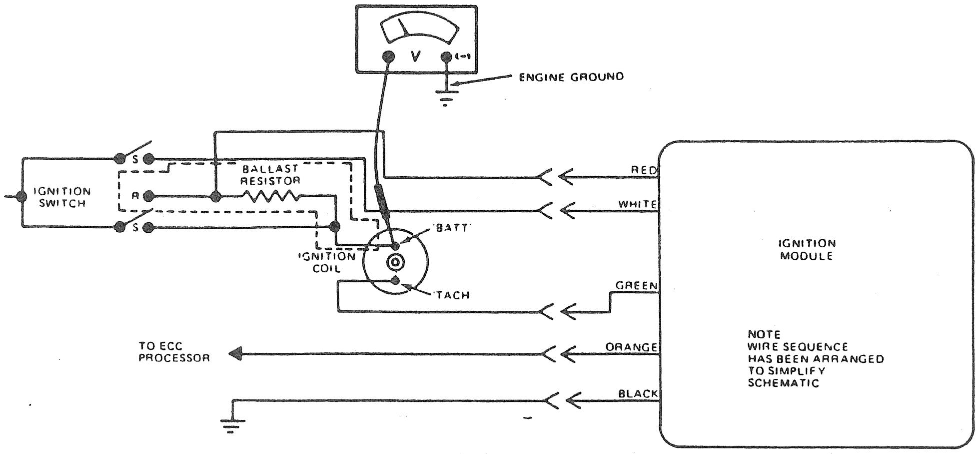


FIGURE 7-38
Testing coil supply voltage. (Courtesy of Ford Motor Co.)

9. If the readings are at least 90 percent of battery voltage, proceed to Test 8.

10. Remove the straight pins and repair the wire insulation.

11. Reconnect the cable or wire removed from the starter relay.

Test 8—Ignition Coil Supply Voltage

Check the supply voltage to the ignition coil in the RUN mode by doing the following:

1. Connect the negative (−) voltmeter lead to a good engine ground (Fig. 7-38).

2. Turn the ignition switch to the RUN position.

3. With the positive (+) voltmeter lead, measure the voltage at the BATT terminal of the ignition coil.

4. Turn the ignition switch off.

5. If the voltage reading is between six volts and eight volts, perform a continuity check of the wiring harness to the ignition module. If the harness wiring is okay, replace the ignition module. If available, use a module tester to verify that the unit is defective.

6. If the voltage reading is less than six volts or greater than eight volts, proceed with Test 9.

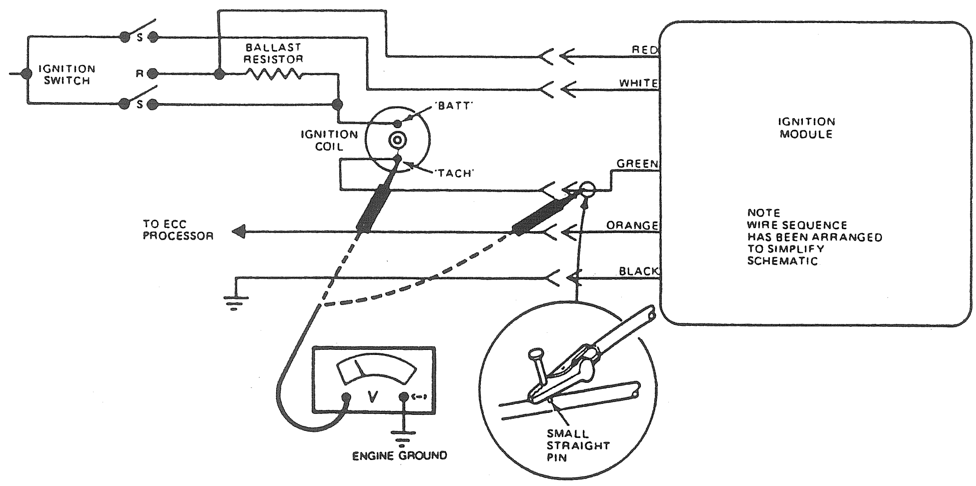


FIGURE 7-39
Checking the coil to module wire. (Courtesy of Ford Motor Co.)

Test 9—Module to Coil Wire

To test the voltage drop across the ignition module to the coil wire, do the following:

1. Carefully insert a small straight pin into the green module wire (Fig. 7-39).

Caution: Do not allow the pin to contact an electrical ground.

2. Attach the negative (−) voltmeter lead to a good engine ground.

3. Turn the ignition switch to the RUN position.

4. With the positive (+) voltmeter lead, measure and compare the voltage at the green module wire and the TACH terminal of the ignition coil.

5. Turn the ignition switch off.

6. If the voltage reading difference is greater than 0.5 volt, remove the straight pin and inspect the wiring harness between the ignition module and the coil.

7. If the voltage reading difference is 0.5 volt or less, proceed to Test 10.

Test 10—Primary Circuit Voltage Drop and Continuity

Check the RUN mode voltage drop and the continuity of the primary circuit between the ignition coil and the module by doing the following:

1. Attach the negative (−) voltmeter lead to a good engine ground (Fig. 7-40).

2. Insert a straight pin into the green module wire.

Caution: Make sure the pin does not contact an electrical ground.

3. Turn the ignition switch to the RUN position.

4. With the positive (+) voltmeter lead, measure the voltage at the green module wire.

5. Turn the ignition switch off.

6. If the voltage reading is greater than 1.5 volts, proceed to Test 12.

7. If the voltage reading is 1.5 volts or less, go to Test 11.

8. Remove the straight pin and repair the wire insulation.

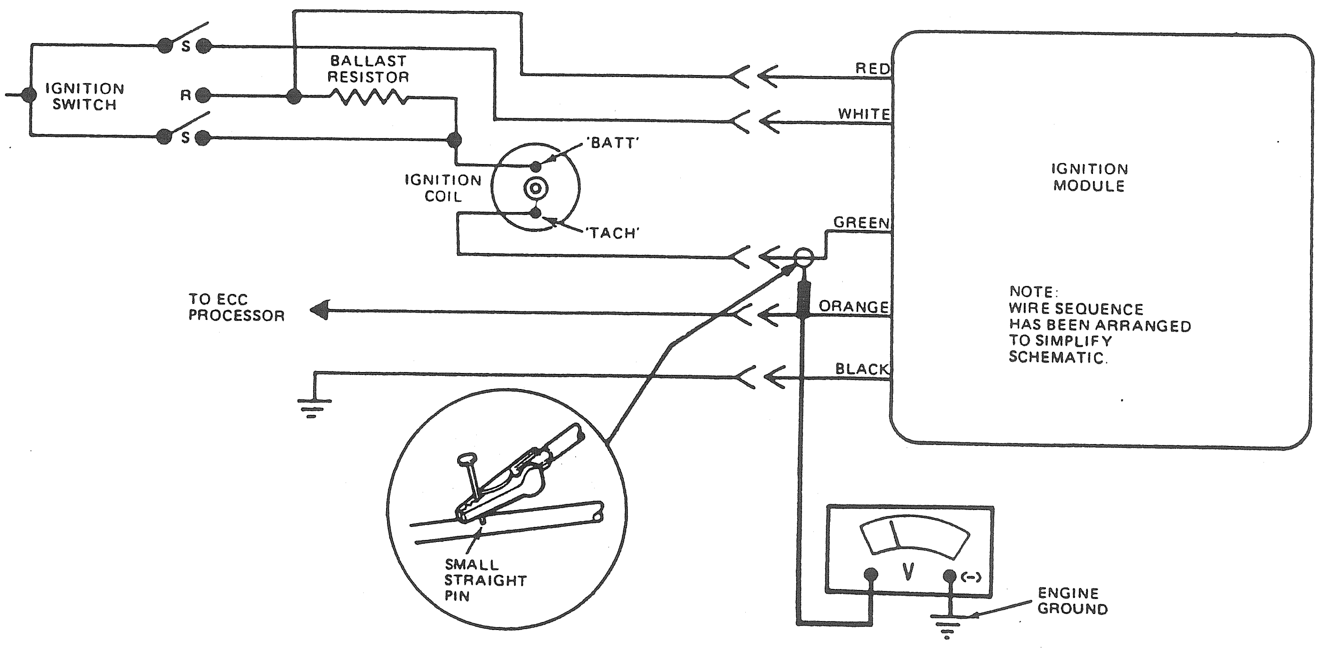


FIGURE 7-40
Testing primary circuit continuity. (Courtesy of Ford Motor Co.)

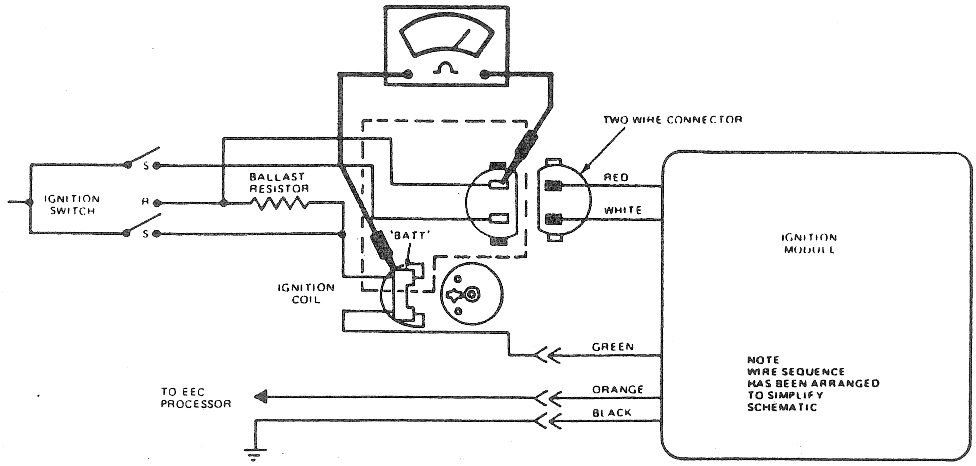


FIGURE 7-41
Checking the ballast resistor. (Courtesy of Ford Motor Co.)

Test 11—Ballast Resistor

Check the resistance within the ballast resistor by doing the following:

1. Separate and inspect the ignition module two-wire connector.

2. Remove the ignition coil connector.

3. Using the ohmmeter leads, measure the resistance between the BATT terminal of the ignition coil connector and the wiring harness connector with the red module wire (Fig. 7-41).

4. If the resistance is to specifications, the ballast resistor is satisfactory.

5. If the resistance is less or more than specifications, replace the ballast resistor.

6. After the test is over, assemble all connectors in their proper locations.

Test 12—Wiring Harness Ground Circuit

Check the continuity of the wiring harness ground circuit by doing the following:

1. Separate the ignition module three-wire connector, and inspect it for dirt, corrosion, and damage.

2. Attach one ohmmeter lead to a good engine ground (Fig. 7-42).

3. Use the other ohmmeter lead to measure the

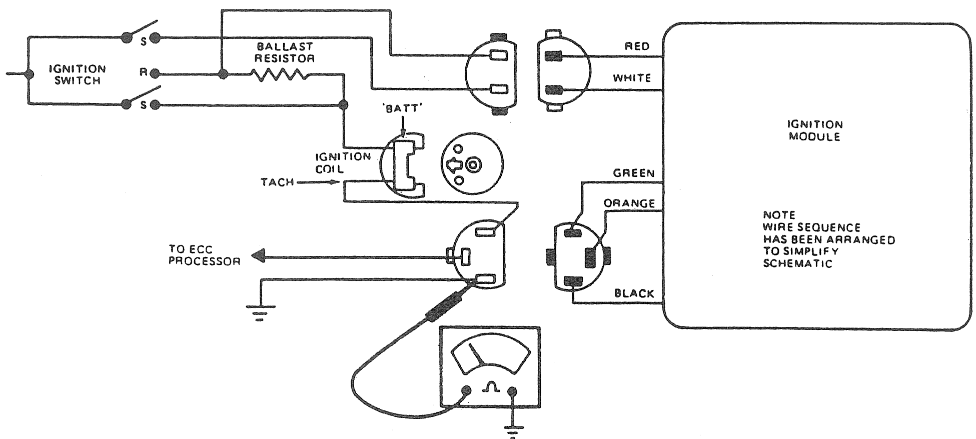


FIGURE 7-42
Testing the wiring harness ground circuit. (Courtesy of Ford Motor Co.)

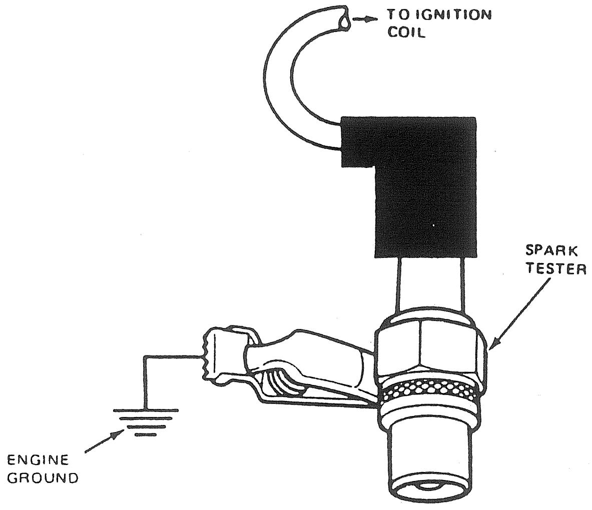


FIGURE 7-43
Checking secondary coil voltage. (Courtesy of Ford Motor Co.)

resistance in the harness terminal with the black module wire. Wiggle the wiring harness while making the measurement.

4. If the resistance is one ohm or less, the ground circuit is okay.

5. If the resistance is greater than one ohm, inspect the wiring harness and connector between the ignition module and the ground connection.

6. After the test is over, assemble the ignition module connector.

7-4 TESTING A FORD TFI-IV IGNITION

The following is a step-by-step procedure for locating the cause of a no-start condition in a Ford TFI-IV ignition system. If the engine operates but performs poorly, you should use the secondary and timing diagnostic procedures presented earlier. Just keep in mind that there are some differences between the TFI-IV and the other systems. *Always use the calibration code to verify the system type, and use the data from the emission decal and service manuals to determine specifications and service instructions.*

Test 1—Ignition Coil Secondary Voltage

To determine whether the E coil is providing sufficient secondary voltage for the spark plugs, do the following:

1. Disconnect the coil high tension cable from the distributor.

2. Attach the spark tester to a good engine ground and connect the high tension cable to the plug (Fig. 7-43).

3. While observing the spark tester, have an assistant crank the engine over using the ignition switch.

4. If there is a good spark at the tester, inspect the rotor and distributor cap for damage, carbon tracking, or cracks. Replace the rotor and cap as necessary.

5. If there is no spark at the tester, use an ohmmeter to measure the resistance in the coil wire. If the resistance value is greater than the specifications, replace the cable. Also, inspect the coil for cracks, damage, and carbon tracking, and replace it as necessary. If the cable and coil are okay, proceed to Test 2.

6. Remove the spark tester and reconnect the coil wire.

Test 2—Ignition Coil Primary Circuit Switching

To see if the primary circuit is switching on and off properly, do the following:

1. Separate the wiring harness connector from the ignition module. Inspect the connector for dirt, corrosion, and damage. Assemble the harness connector.

2. Attach one lead of a 12-volt test light to a good engine ground (Fig. 7-44).

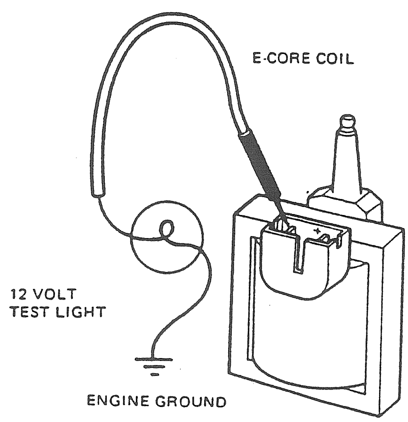


FIGURE 7-44
Testing the primary switching circuit. (Courtesy of Ford Motor Co.)

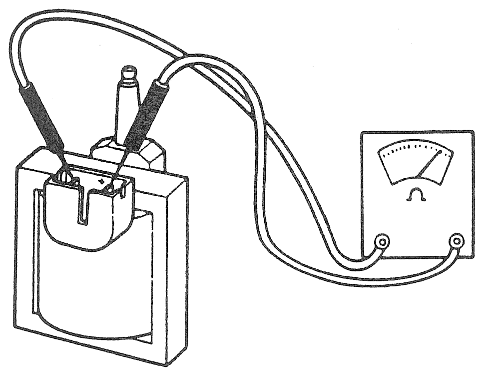


FIGURE 7-45
Checking primary coil resistance. (Courtesy of Ford Motor Co.)

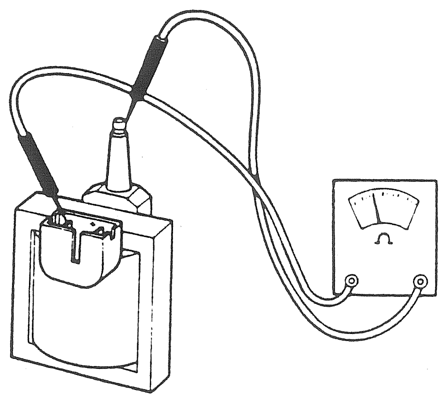


FIGURE 7-46
Testing secondary coil resistance. (Courtesy of Ford Motor Co.)

3. Install the other lead on the TACH terminal of the E coil.

4. Observe the test light as an assistant cranks the engine over using the ignition switch.

5. Turn the ignition key off.

6. If the test light flashes, proceed to Test 3.

7. If the test light comes on but does not flash, go to Test 5.

8. If the test light is very dim or does not come on, proceed to Test 8.

Test 3—Ignition Coil Primary Resistance

To check the total resistance of the E coil's primary windings against specifications, do the following:

1. Disconnect the ignition coil connector. Inspect it for dirt, corrosion, and damage.

2. Using the ohmmeter leads, measure the resistance between the two primary terminals of the coil (Fig. 7-45).

3. If the resistance is to specifications, the primary windings are okay. Proceed to Test 4.

4. If the resistance is below or above specifications, replace the ignition coil.

Test 4—Ignition Coil Secondary Resistance

To check the total resistance of the E coil's secondary windings against specifications, do the following:

1. Remove the high tension cable from the coil.

2. Using the ohmmeter leads, measure the resistance from the positive (+) primary terminal to the high voltage secondary terminal (Fig. 7-46).

3. If the total resistance is within specifications, proceed to Test 5.

4. If the resistance is less or more than specifications, replace the coil.

5. After the test is complete, reinstall the connector and high tension cable.

Test 5—Wiring Harness

This test checks the supply voltage in the wiring harness to the module to make sure the supply voltage is within 90 percent of that provided by the battery. Follow these directions to complete the test:

1. Separate the wiring harness from the ignition module. *Note: Push on the connector tabs to separate.* Inspect the wiring harness for dirt, corrosion, and damage.

2. Disconnect the S terminal of the starter relay.

3. Attach the negative (−) lead of the voltmeter to the distributor base.

4. With the positive (+) lead, measure and record battery voltage.

5. Install a straight pin into the terminal of the connector (Fig. 7-47).

Caution: *Do not allow the pin to contact an electrical ground.*

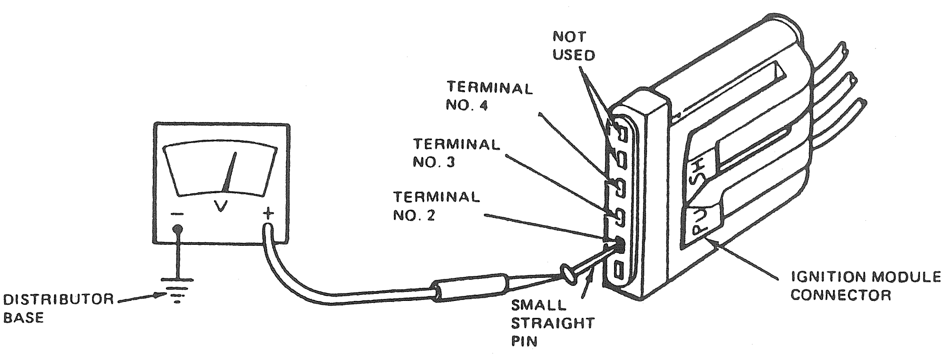


FIGURE 7-47
Checking the wiring harness for supply voltage. (Courtesy of Ford Motor Co.)

6. Following the table shown in Fig. 7-48 and the positive (+) voltmeter lead, measure the terminal voltage at the straight pin locations with the ignition switch positioned as indicated.

7. Turn the ignition switch off.

8. If the voltage readings are at least 90 percent of the one taken in Step 4, proceed to Test 6.

9. If a voltage reading is less than 90 percent of the one taken in Step 4, refer to the vehicle wiring diagrams for the appropriate circuit, and inspect its wiring harness and connectors. If they are satisfactory, replace the ignition switch.

10. Remove the straight pin from the connector.

11. Reconnect the wire to the S terminal on the starter relay.

CONNECTOR TERMINAL	WIRE/CIRCUIT	IGNITION SWITCH TEST POSITION
#2	TO IGNITION COIL (–) TERMINAL	RUN
#3	RUN CIRCUIT	RUN AND START
#4	START CIRCUIT	START

FIGURE 7-48
Test points and switch positions for the voltage supply checks. (Courtesy of Ford Motor Co.)

Test 6—Ignition Coil Primary Voltage

To check the voltage at the negative terminal of the E coil against that of the battery, do the following:

1. Attach the negative (–) lead of the voltmeter to the distributor base.

2. With the positive (+) voltmeter lead, measure and record battery voltage.

3. Turn the ignition switch to the RUN position.

4. With the positive (+) voltmeter lead, measure the voltage at the negative (–) terminal of the E coil (Fig. 7-49).

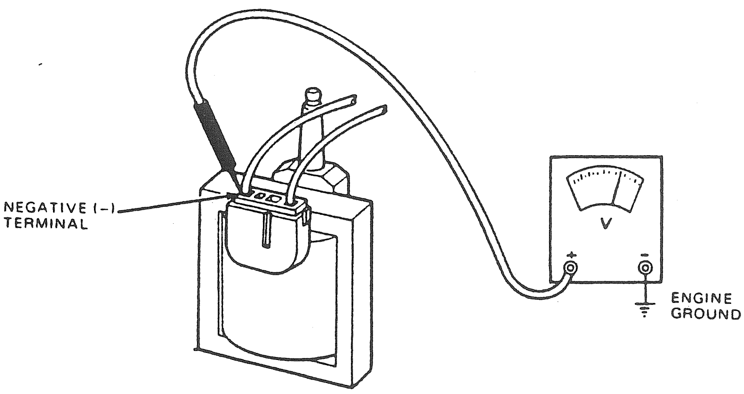


FIGURE 7-49
Checking ignition coil primary voltage. (Courtesy of Ford Motor Co.)

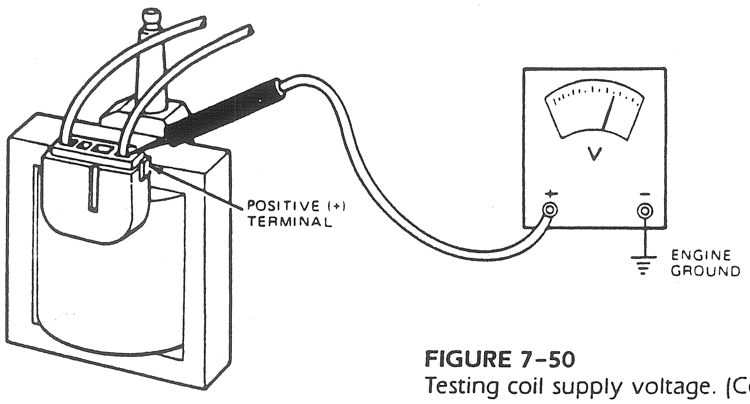


FIGURE 7-50
Testing coil supply voltage. (Courtesy of Ford Motor Co.)

5. Turn the ignition switch off.

6. If the voltage reading is 90 percent of that from the battery, the circuit is satisfactory.

7. If the voltage reading is less than 90 percent of that from the battery, inspect the wiring harness between the ignition module and the coil negative terminal, and then go to Test 7.

Test 7—Ignition Coil Supply Voltage

To test the voltage at the positive terminal of the E coil against that of the battery, do the following:

1. Attach the negative (−) voltmeter lead to the distributor base.

2. With the positive (+) voltmeter lead, measure and record battery voltage.

3. Turn the ignition switch to the RUN position.

4. With the positive (+) voltmeter lead, measure the voltage at the positive terminal of the ignition coil (Fig. 7-50).

5. Turn the ignition switch off.

6. If the reading is within 90 percent of that provided by the battery, inspect the ignition coil and connector terminals for dirt, corrosion, or damage, and proceed to Test 8.

7. If the reading is less than 90 percent of that provided by the battery, inspect and service the wiring between the ignition coil and switch. Also, check for a worn or damaged ignition switch.

Test 8—EEC-IV and TFI-IV Signal

To test the ignition module signal from the electronic control assembly, do the following:

1. Connect the coil high tension cable to a spark tester.

2. Push the tabs and separate the wiring harness connector from the ignition module. Inspect it for dirt, corrosion, and damage, and then reassemble the connector.

3. Separate the inline base timing connector.

4. While observing the spark tester, have an assistant crank the engine over with the ignition switch.

5. If there is a spark at the tester, check the ignition module signal wire for continuity. If the wire is okay, proceed to the electronic engine control diagnostic section of the service manual.

6. If there is no spark at the tester, go to Test 9.

Test 9—Distributor and TFI-IV Module

Check the operation of the PIP sensor in the distributor and the module by doing the following:

1. Remove the distributor assembly from the engine.

2. Install a new TFI-IV module onto the distributor.

3. Connect the harness to the TFI-IV module.

4. Ground the distributor with a jumper lead.

5. Rotate the distributor by hand with the ignition switch in the RUN position, and observe the spark tester.

6. If there is a spark, replace the old distributor with the new module.

7. If there is no spark, replace the distributor with the old module because the PIP sensor is defective.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. The TFI-IV system uses what type of coil [7-4]?
2. Before testing an ignition system, why must the battery be fully charged [7-1]?
3. What test procedure is not necessary when checking a no-start condition on an engine with a Duraspark III ignition system [7-3]?
4. What is the first step in locating the cause of a no-start condition [7-2]?

REVIEW

1. A Ford vehicle with a TFI-IV ignition system will not start. How do you test the ignition module [7-4]?
   a. use an aftermarket tester
   b. use a voltage drop test
   c. both a and b
   d. neither a nor b
2. Technician A states that ignition parts for Ford systems are usually not interchangeable, but Technician B says that all system parts are interchangeable [7-1]. Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
3. If the TFI-IV system will not pass the primary switching test, which component may be at fault [7-4]?
   a. the secondary coil windings
   b. the primary coil windings
   c. both a and b
   d. neither a nor b
4. During testing procedures, how long is it safe to operate an engine with a spark plug not firing [7-1]?
   a. five minutes
   b. two minutes
   c. both a and b
   d. neither a nor b
5. If an engine with a TFI-IV system passes the secondary voltage test but will not start, what component should be inspected [7-4]?
   a. the distributor cap
   b. the rotor
   c. both a and b
   d. neither a nor b
6. How should a wire punctured during a test procedure be repaired [7-1]?
   a. Tape should be wrapped around the punctured area.
   b. Nonacetic RTV compound should be spread on the area.
   c. both a and b
   d. neither a nor b
7. When checking a Duraspark III system, the ignition coil supply voltage test measures [7-3]
   a. the voltage drop in the circuit to the coil.
   b. the voltage drop across the coil itself.
   c. both a and b.
   d. neither a nor b.
8. How is the voltmeter connected to test voltage drop [7-1]?
   a. in series
   b. in parallel
   c. both a and b
   d. neither a nor b
9. While testing which ignition system is an ignition system test adapter needed [7-3]?
   a. Duraspark II
   b. Duraspark III
   c. both a and b
   d. neither a nor b
10. For checking secondary output voltage, the spark tester replaces what other test component(s) [7-1]?
    a. the modified plug and jumper wire
    b. the module tester
    c. both a and b
    d. neither a nor b
11. If the coil's secondary resistance gives a satisfactory measurement but the primary does not, what must be done [7-2]?
    a. check the module harness

b. replace the ignition switch
c. both a and b
d. neither a nor b

12. Before attempting testing or service, where can you find exact information for the ignition system installed on a given Ford vehicle [7-1]?
    a. the manuals
    b. the calibration code
    c. both a and b
    d. neither a nor b

13. How can tapping on a Duraspark distributor during the test procedures cause an arc at the spark tester [7-2]?
    a. The resulting vibration induces a voltage in the pickup coil.
    b. The resulting vibration induces a voltage in the primary windings.
    c. both a and b
    d. neither a nor b

14. Technician A states it is not always necessary to follow a troubleshooting guide. Technician B says the troubleshooting guide is not a reliable diagnostic tool. Who is correct [7-1]?
    a. A only
    b. B only
    c. both a and b
    d. neither a nor b

15. If an engine will not start but there is an arc at the spark tester, what may be the cause of the problem [7-2]?
    a. a vacuum leak
    b. a malfunctioning fuel system
    c. an open spark plug wire
    d. a malfunctioning vacuum advance

Chapter 8

CHRYSLER ELECTRONIC IGNITION SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- identify and know the function of the components of a Chrysler electronic ignition system.
- describe the design and operation of the pickup coil assembly found in an electronic ignition system (EIS) distributor.
- explain the operation of both centrifugal and vacuum advance mechanisms.
- describe the design of a Hall-effect EIS.
- describe the design of the Mitsubishi EIS.
- describe the design and explain the operation of the lean burn system.
- describe the function and design of the electronic spark advance and electronic spark control systems.

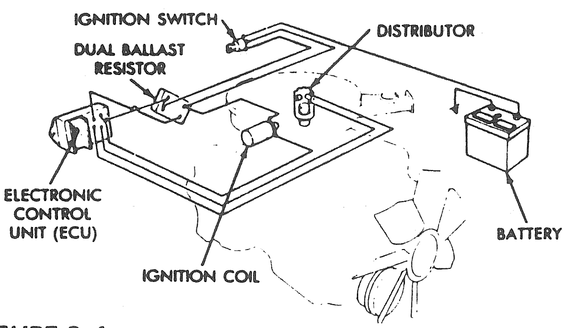


FIGURE 8-1
Chrysler electronic ignition system (EIS). (Courtesy of Chrysler Motors Corp.)

Chrysler Corporation first introduced its electronic ignition system (EIS) as a mid-year model change in 1971 passenger cars. In that year, its use was limited to automobiles with 340 CID engines that were equipped with a manual transmission (Fig. 8-1).

In January 1972, engines in light-duty conventional cab and compact trucks had EIS as an option. By June 1972, EIS was made available on 318-3 and 413-1 engines on motor home chassis.

By the end of the 1972 model year, EIS was standard equipment on all V-8 models sold in California, and was available in other states as an extra-cost option. However, since 1973, all North American-built Chrysler automobiles and trucks have the electronic ignition system, which eliminated completely the production of any contact point systems.

Chrysler developed ESI to minimize ignition system maintenance and to help prevent misfiring. Misfiring is a common complaint about the early system and usually results from owner neglect of needed maintenance, especially on the contact points. Furthermore, a misfire in one cylinder can increase undesirable exhaust emissions by as much as ten times.

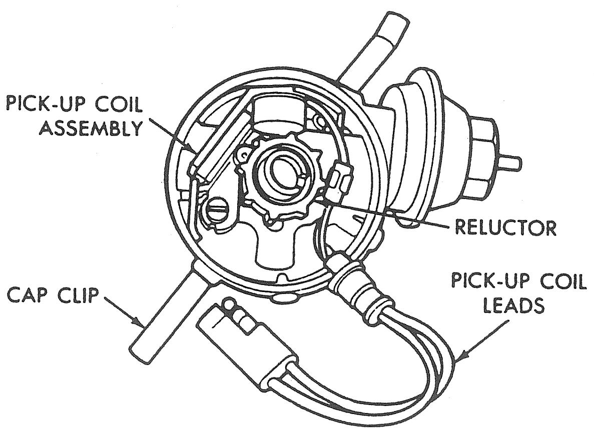


FIGURE 8-2
EIS distributor. (Courtesy of Chrysler Motors Corp.)

EIS eliminates misfires due to inadequate maintenance by eliminating the contact points from the system. The system also very accurately controls dwell and ignition timing, resulting in maximum exhaust emission control and fuel economy.

8-1 DESIGN AND OPERATION OF CHRYSLER ELECTRONIC IGNITION

Chrysler's first EIS is relatively simple in both its design and operation. Outwardly, the EIS looks just like the contact point system used previously. The only apparent outward change is the addition of a control unit and modification of the ballast resistor.

Distributor and Magnetic Pickup Design

The size of the distributor housing and the cap remain unchanged from the contact point system. However, in place of the breaker points and condenser, the EIS uses a pickup coil and a gear-like ferrous element similar to that found in the Ford SSI and Duraspark I and II systems (Fig. 8-2).

The Chrysler pickup assembly consists of a permanent magnet attached to a pole piece. The pole piece is an extension of the mounting bracket and attaches to the permanent magnet. Because of this arrangement, the pickup unit resembles a horseshoe-type magnet with the reluctor end of the pole piece acting as one of the magnetic poles.

Wound near the end of the pole piece is a coil of insulated wire. Each of the ends of this coil connects to one of the pickup coil leads. On the opposite end of the leads is a harness connector.

The spoked ferrous element in the EIS distributor is known as the reluctor. The reluctor attaches to the distributor shaft and has a tooth for each of the engine cylinders. Like the armature in the Ford system, the reluctor reduces the magnetic resistance of the field from the permanent magnet.

Pickup Coil Operation

The permanent magnet of the pickup coil assembly produces a magnetic field from the pole piece to the bracket supporting the permanent magnet. This magnetic field passes through the coil that is wound around the pole piece (Fig. 8-3). Without the influence of the reluctor teeth, the magnetic field is relatively weak because of the air gap between the pole piece and the support bracket.

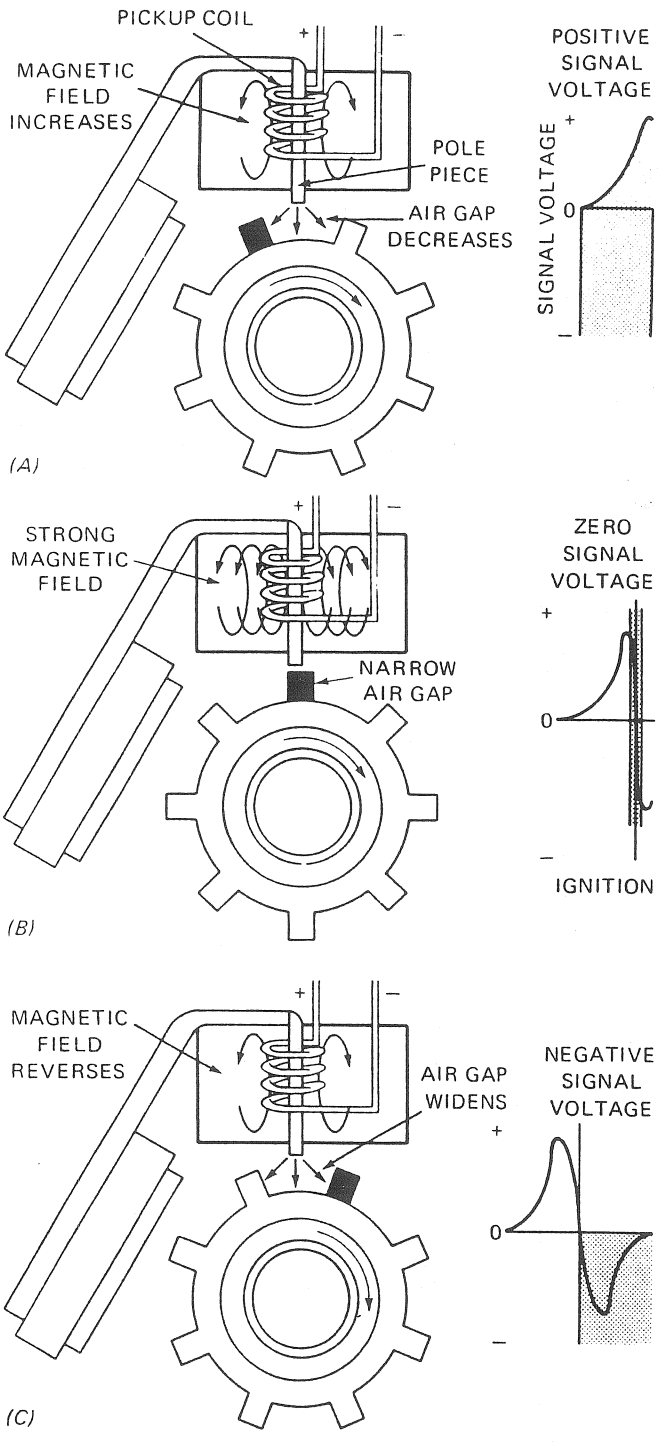


FIGURE 8-3
Operation of the pickup coil. (Courtesy of Chrysler Motors Corp.)

But as one of the reluctor teeth enters the magnetic field, the tooth provides a better path for the magnetism. This increases the magnetic field surrounding the pickup coil. Increasing the field strength at the coil induces a positive voltage at one of its terminals (Fig. 8-3A). This voltage is proportional to the rate of change of the magnetic field.

The level of the positive voltage continues to build until the reluctor tooth approaches the pole piece. However, voltage falls to zero when the tooth is directly aligned with the pole piece (Fig. 8-3B). Even though the magnetic field strength is the strongest when a tooth is aligned with the pole piece, the rate of magnetic field density change is zero at this point. For this reason, voltage rapidly drops to zero.

As the tooth continues to move away, there is an induction of a negative voltage at the same terminal of the pickup coil (Fig. 8-3C). This is due to the collapse or reversal of the magnetic field through the pickup coil. This negative voltage is induced again by the change, in this case reduction, in field strength. Remember, no voltage is induced in the pickup coil unless the reluctor is moving. The rapid increase and decrease of the magnetic field as the rotating reluctor teeth approach and pass the pole piece is what induces first the positive and then the negative voltage into the same pickup coil terminal.

The change of the strength of the magnetic field induces an AC analog voltage signal. This signal is used by the electronic control unit (ECU) to close and open the coil's primary circuit.

Ballast Resistor

The Chrysler EIS uses a dual *ballast resistor* (Fig. 8-4). This resistor plays a dual role. On the one side is a 0.5-ohm resistor, which is a voltage-limiting de-

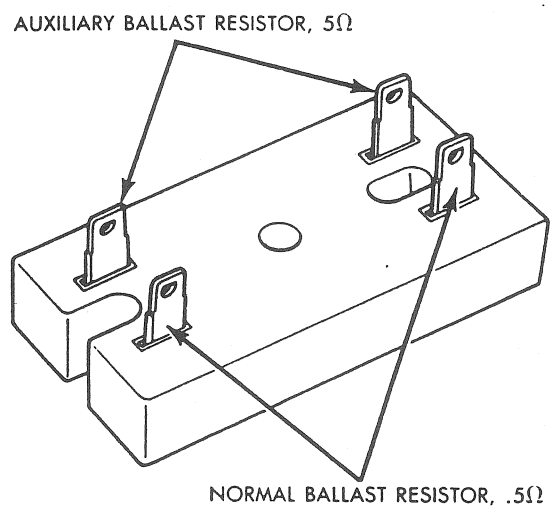


FIGURE 8-4
Dual ballast resistor. (Courtesy of Chrysler Motors Corp.)

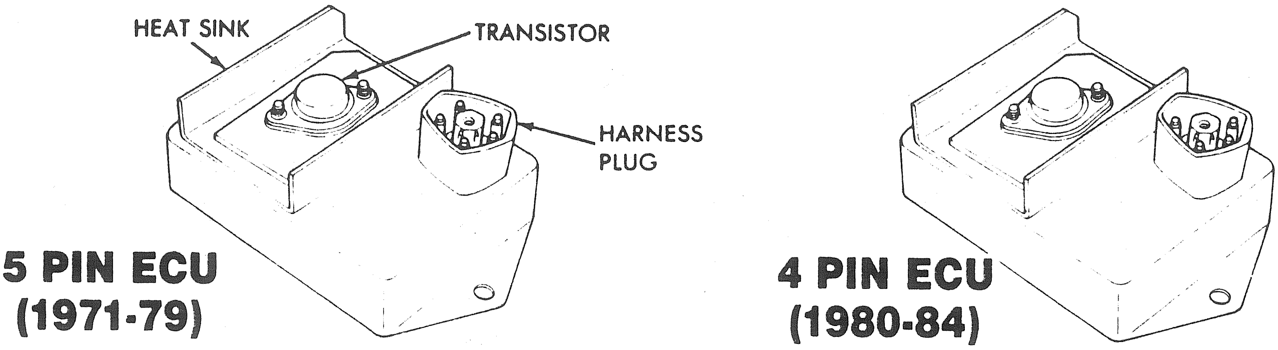


FIGURE 8-5
Electronic control unit. The 1971–1979 modules have a five-pin connector, while 1980 and later models use a four-pin connector. (Courtesy of Chrysler Motors Corp.)

vice that maintains constant primary current flow even with variations in engine speed. This protects the ignition coil against high current flow at low engine speeds. However, this resistor is bypassed during engine cranking so that full battery voltage is applied to the coil primary circuit.

On the other side of the dual unit is a 5.0-ohm resistor. This is also a voltage-limiting device to control current flow. But in this case, the resistor limits the current flow through the electronic part of the ECU.

Electronic Control Unit (ECU)

The *electronic control unit (ECU)* is the heart of the EIS (Fig. 8-5). It consists of a switching transistor and electronic circuitry. The *switching transistor* opens and closes the coil primary circuit. The function of the ECU circuitry is to determine how long the ignition coil primary circuit remains open and closed. Moreover, the closed period, when current flows in the primary (i.e., the dwell period), must vary with engine speed, which is measured in crankshaft rotations. Since the control unit circuitry is sealed and has no moving parts, the desired dwell rate is established and cannot be adjusted.

The switching transistor mounts on the exterior of the ECU in a *heat sink* that is necessary for cooling. The ground circuit for the ECU is through its mounting bolts. In addition, the ECU connects into the ignition via an exterior connector.

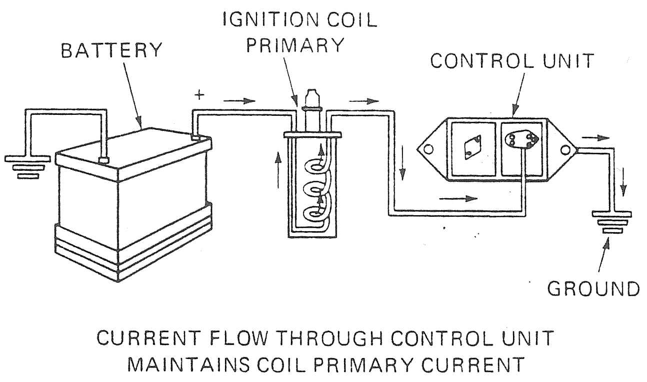


FIGURE 8-6
Electronic control unit (ECU) operation with a positive pickup coil signal.

ECU Operation

As a reluctor tooth approaches the pole piece, there is a small but positive voltage signal induced in the pickup coil. This tiny signal is fed via the harness to the ECU. The positive signal, in turn, turns on the switching transistor (Fig. 8-6). As a result, battery current flows through the primary windings of the coil and then through the ECU to ground. The switching transistor remains on as long as there is a positive pickup coil signal.

As the reluctor tooth aligns and then passes the pole piece, the pickup coil voltage signal drops first to a positive zero and then turns negative at the output terminal (Fig. 8-7). The positive zero signal turns off the switching transistor, and it remains off as long as there is a negative voltage applied to it. When the switching transistor turns off, current cannot flow through the ECU to ground. Consequently, this interrupts the flow of current through the primary coil windings.

Ignition Coil Function and Design

The *ignition coil* is nothing more than an electrical transformer. This unit steps up battery voltage through magnetic induction until it is high enough

to bridge the spark plug gap during all phases of engine operation (Fig. 8-8).

To function as a transformer, the coil assembly is made up of two sets of windings that are wound around a soft, laminated iron core. Wound nearest the core are the *secondary windings,* which consist of as many as 22,000 turns of approximately #38, fine, insulated wire. One end of the windings connects to the high tension terminal, while the other attaches to the positive (+) primary terminal.

The outer windings are the *primary windings,* which consist of about 200 turns of #20 insulated wire. One end of this winding attaches to the primary positive (+) terminal and the other to the negative (−) terminal.

The windings and core are sealed into a metal housing. The housing is filled with oil to serve as a coolant and to provide additional insulation.

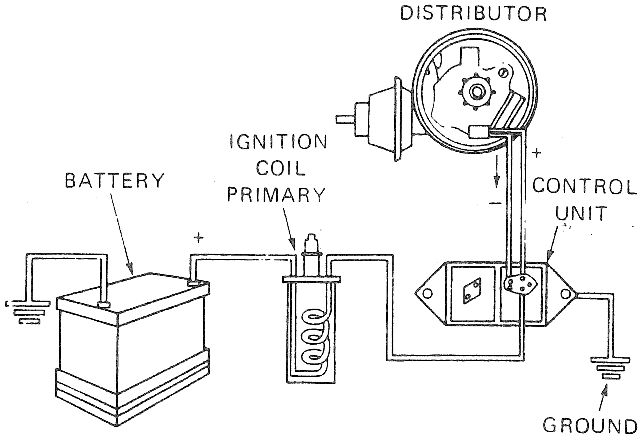


FIGURE 8-7
ECU operation with a negative pickup coil signal.

Coil Operation

From the battery, current flow in the primary coil enters at the (+) terminal and then flows through the larger windings. With the switching transistor on, the electronic control unit (ECU) becomes the ground for the primary current flow. With current flowing through the primary windings to ground, the coil builds up a magnetic field.

As the switching transistor turns off, the primary current cannot reach ground through the ECU. When the primary circuit opens, the magnetic

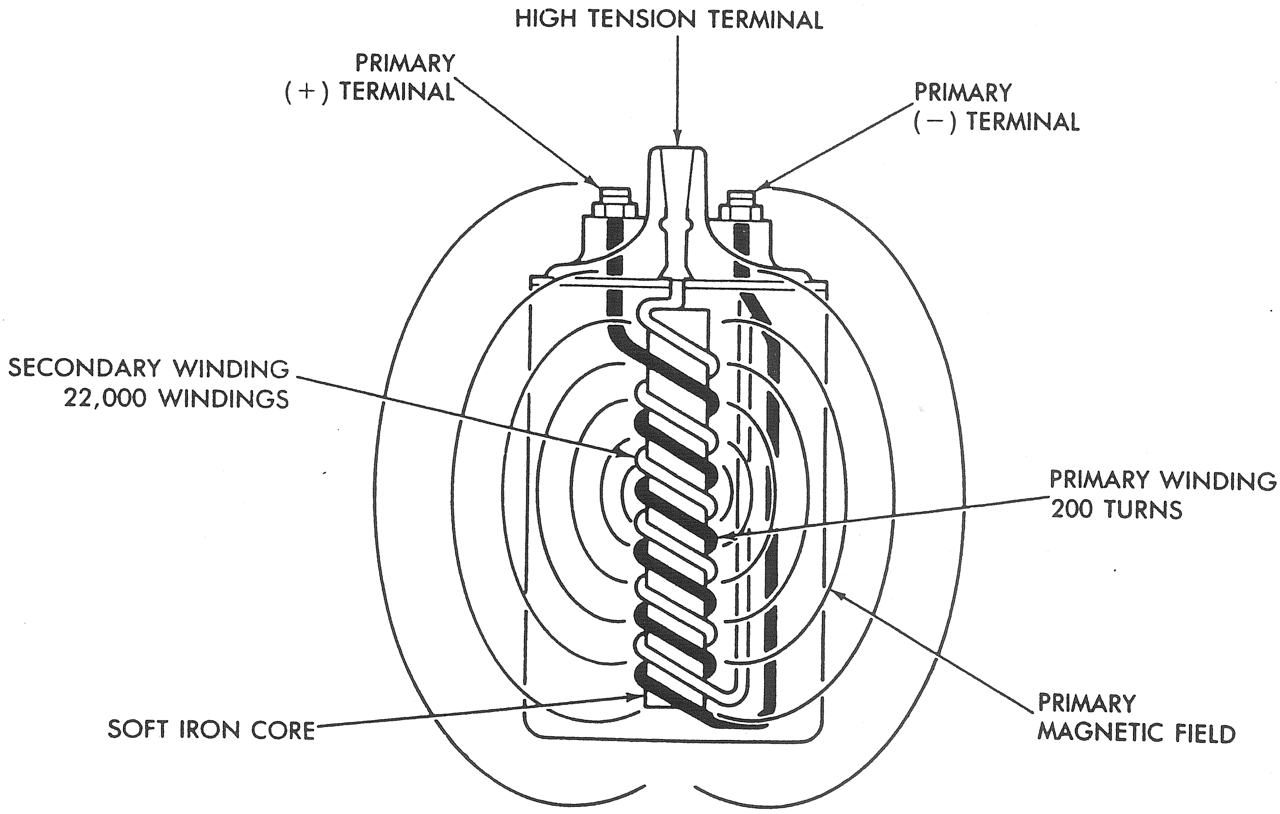


FIGURE 8-8
EIS ignition coil. (Courtesy of Chrysler Motors Corp.)

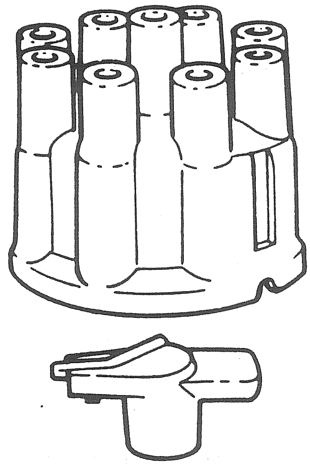


FIGURE 8-9
Rotor and distributor cap. (Courtesy of Chrysler Motors Corp.)

field collapses across both windings. This induces a high voltage in the thousands of turns of the secondary windings. The coil develops this high secondary voltage at the high tension terminal.

Due to the ratio of the primary to secondary windings, the voltage is stepped up about a hundred times. That is, if 250 volts are induced in the primary windings, the secondary voltage at the terminal can be 25,000 volts. However, the secondary current flow will be reduced below that flowing in the primary as the voltage is increased. In other words, the induced secondary voltage is extremely high, but the amount of current flow is very small, from 0.001 ampere to 0.002 ampere.

Rotor and Cap

The rotor operates in conjunction with the cap to distribute the high voltage, low amperage surges from the ignition coil to the individual spark wires in the firing order (Fig. 8-9). The rotor has a spring-loaded blade electrode that maintains contact with the inside-center carbon terminal of the distributor cap.

When the high voltage surge enters the distributor center electrode via the coil's high tension wire, it travels through the rotor electrode. The current then arcs across the small air gap of several thousandths of an inch that is between the rotor electrode and the spark plug terminal inside the cap.

From the terminal inside the cap, current flows to the outer cap's spark plug wire sockets. The spark plug wires, or cables, are arranged in these sockets according to the firing order of the engine and in the direction of distributor shaft rotation. The number one cable is installed in the cap corresponding to the rotor position when the first cylinder is top dead center (TDC) of its compression stroke.

Secondary Ignition Cables

The spark plug wires, including the coil lead, are referred to as *high tension* or *secondary ignition cables* (Fig. 8-10). These cables carry the high voltage arc from the coil to the cap and from the cap to the spark plugs. The coil wire is of the same type of construction as the plug cables.

The cables are the resistance type for radio noise suppression. Factory-installed wires have the words "Electronic Suppression" printed on the cable jacket. The cable itself is a graphite-impregnated woven fiber with hypalon insulation to resist electrical leakage. When underhood temperatures are expected to be high due to the operation of emission control equipment, a silicone-rubber jacket is used to resist heat.

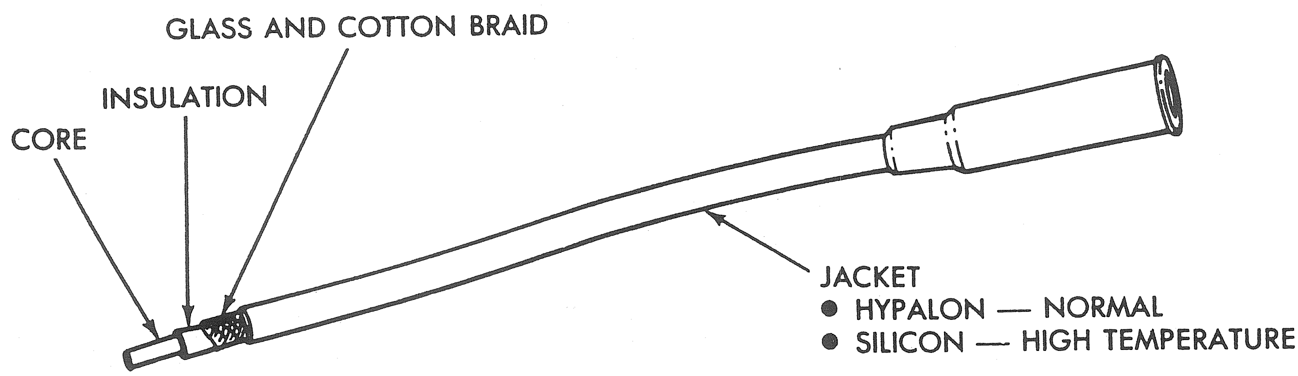


FIGURE 8-10
Secondary ignition cable. (Courtesy of Chrysler Motors Corp.)

8-2 CONVENTIONAL ADVANCE MECHANISMS

The EIS utilizes a conventional spark advance system that includes centrifugal and vacuum advance mechanisms. Both of these assemblies advance the ignition firing from the basic, or initial, timing.

Centrifugal Mechanism

The *centrifugal advance mechanism* is interconnected between the distributor shaft and the reluctor (Fig. 8-11). This mechanism is used to vary the reluctor position in relation to engine speed. To do this, the mechanism has weights that are thrown outward by centrifugal force. This movement is resisted by the action of calibrated springs.

As engine speed increases, the centrifugal force on the weights overcomes spring tension, and the weights swing outward, thereby advancing the reluctor in the direction of distributor shaft rotation. This causes the reluctor to enter the pickup coil assembly's magnetic field sooner, and thus advances the ignition timing.

Vacuum Advance Mechanism

The *vacuum advance mechanism* is necessary to alter ignition timing during part-throttle operation (Fig. 8-12). This form of advanced timing provides maximum fuel economy.

During part-throttle cruise operation, the air/fuel mixture requires more time to burn in order to obtain the best economy. The vacuum mechanism provides the extra time by simply advancing the ignition timing to start the burning process earlier in the cycle. The mechanism accomplishes this task by means of a diaphragm unit connected to the pickup plate assembly within the distributor.

Since the carburetor's ported vacuum varies with throttle valve position, the vacuum advance mechanism provides a means of sensing part-throttle conditions. As the carburetor throttle valve is opened from the idle to part-throttle position, the ported engine vacuum applies itself to the vacuum diaphragm unit. The vacuum acting on the diaphragm causes the pickup coil assembly to turn opposite to the distributor shaft rotation. This action causes the pickup coil to sense the reluctor's tooth position sooner, thus advancing the timing.

But as the throttle plate is closed from part-throttle to idle, the vacuum signal to the diaphragm unit is cut off. The spring within the unit acting on the diaphragm causes the pickup assembly to return to its fully retarded position.

When the engine is in a steady, part-throttle, cruising condition at about 40 mph (64 km/h) on a level road, both the vacuum and centrifugal mechanisms are advancing the spark in correct proportion to engine load and speed, respectively. If the driver accelerates to the wide-open throttle position, the ported engine vacuum drops to near zero. This causes the vacuum diaphragm spring to force the pickup assembly into the retarded position. However, the centrifugal mechanism continues to provide the needed ignition advance based on the engine speed necessary for acceleration.

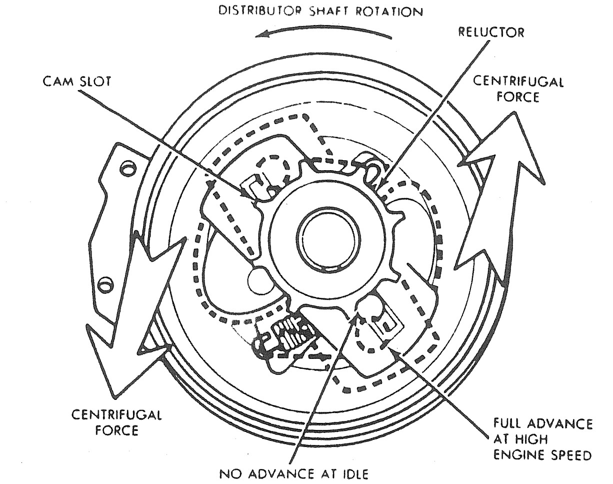


FIGURE 8-11
Centrifugal spark advance. (Courtesy of Chrysler Motors Corp.)

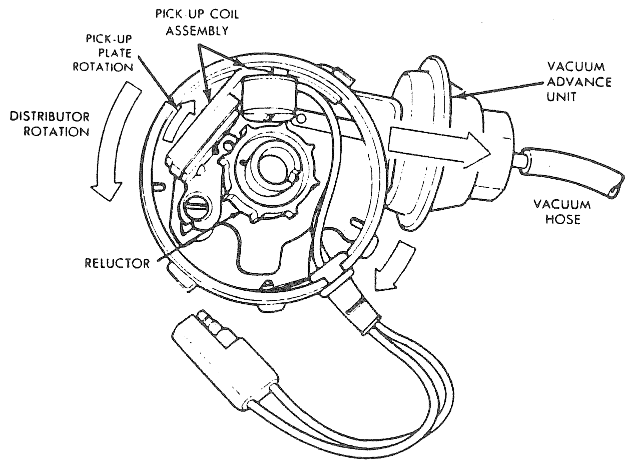


FIGURE 8-12
Vacuum spark advance. (Courtesy of Chrysler Motors Corp.)

8-3 HALL-EFFECT EIS

For one year, in 1980, Chrysler placed a Hall-effect EIS on its Federal Omnis and Horizons, which are both four-cylinder vehicles (Fig. 8-13). This system required no ballast resistor but used the conventional centrifugal and vacuum advance mechanisms within the distributor.

Hall-effect Pickup

In place of a coil-type pickup assembly, the system has a Hall-effect pickup that is similar in design and operation to the Ford PIP sensor. The *Hall-effect pickup* produces a DC voltage pulse as the distributor shaft rotates. This pulse is controlled by a magnetic field. The ECU uses this signal to trigger the switching transistor, which controls the primary coil's ground circuit.

The Hall-effect pickup consists of an integrated circuit (IC) and a permanent magnet, both of which mount onto the pickup plate. The permanent magnet faces the IC with an air gap between them.

The distributor rotor has downstanding shutter blades with spaces between them, one for each of the four engine cylinders. The pickup plate, located in the distributor housing, has a gate through which the shutter blades pass as the distributor shaft rotates. If a shutter is in the gate, it blocks the air gap between the permanent magnet and the IC. This changes the magnetic field strength through the IC and causes its Hall voltage to vary.

As the shutters and spaces of the rotor pass through the air gap, the Hall-effect pickup produces a pulsating DC sine wave signal with sharp corners. This signal is fed to the ECU to trigger the switching transistor.

Hall-effect ECU

As in the electronic ignition system, the electronic control unit (ECU) is the only control unit within the Hall-effect system. This special Hall-effect, five-pin ECU mounts on the firewall or fender well and operates when the ignition switch is in the START or RUN position. When turned on, the Hall-effect ECU controls the ground circuit of the primary coil windings, and thus its current flow.

When an open space between shutters is in the gate, the magnetic field can pass through the IC unit. As it does so, it generates a positive Hall voltage. This voltage turns on the switching transistor within the ECU. The ECU, in turn, completes the ground circuit for the primary windings, and current flows.

As a shutter blade enters the air gap, it causes the magnetic field to bypass the IC assembly. This causes the Hall voltage to drop to zero. The zero signal turns off the switching transistor, and the ECU breaks the primary coil's ground circuit.

The voltage signal from the Hall-effect pickup to the ECU is not changed by the speed of the distributor shaft as it is with a coil-type pickup. Therefore, the pickup generates a full-strength Hall voltage signal to the ECU, even at slow cranking speeds.

Hall-effect Distributor Cap and Wires

The Hall-effect EIS uses a redesigned cap and secondary cables (Fig. 8-14). This cap has a vent to prevent moisture build-up inside. In addition, the cap is held in place on the distributor by mounting screws, while the six- and eight-cylinder EIS caps use spring clips. Finally, the cap utilizes a notch or pin to index it, which assures proper seating in the distributor housing.

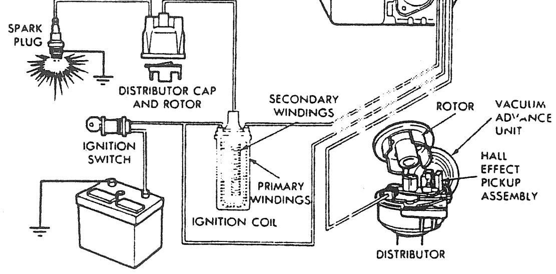


FIGURE 8-13
Hall-effect EIS. (Courtesy of Chrysler Motors Corp.)

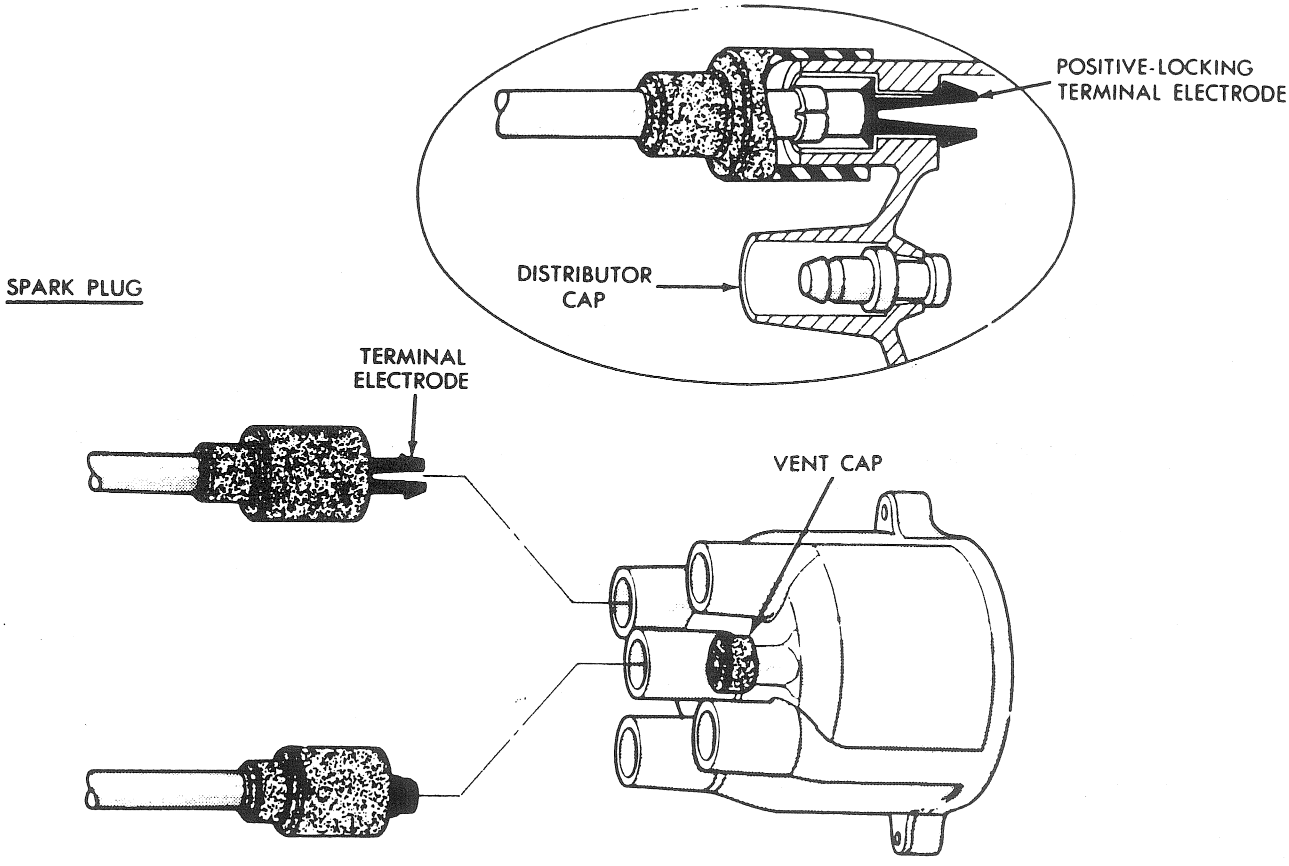


FIGURE 8-14
Hall-effect EIS distributor cap and wires. (Courtesy of Chrysler Motors Corp.)

The secondary cables are the same as in the EIS design, except where each attaches into the cap. The spark plug cables have unique positive-locking terminal electrodes, which provide secure engagement at all times. The locking electrodes also form the internal cap terminals. On the other hand, the coil's high tension wire has a female connection that presses onto a male terminal in the center of the cap.

8-4 MITSUBISHI EIS

Chrysler introduced the Mitsubishi EIS system for use on its 1.4-, 2.0-, and 2.6-liter, four-cylinder engines (Fig. 8-15). The Mitsubishi system uses a distributor with a coil pickup and reluctor. The pickup produces the AC signal used by the ignitor (i.e., the ECU) to close and open the coil primary circuit. The distributor also contains conventional centrifugal and vacuum advance mechanisms.

The ignitor serves the same function as the ECU on other Chrysler systems. The 1979 and 1980 models used an ignitor that mounted on the side of

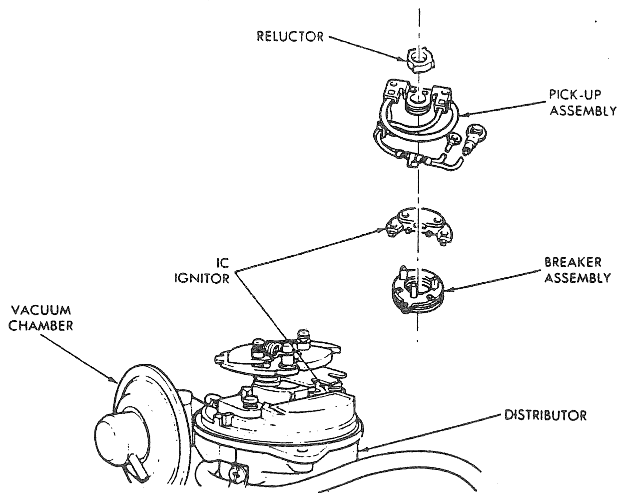


FIGURE 8-15
Mitsubishi EIS distributor. (Courtesy of Chrysler Motors Corp.)

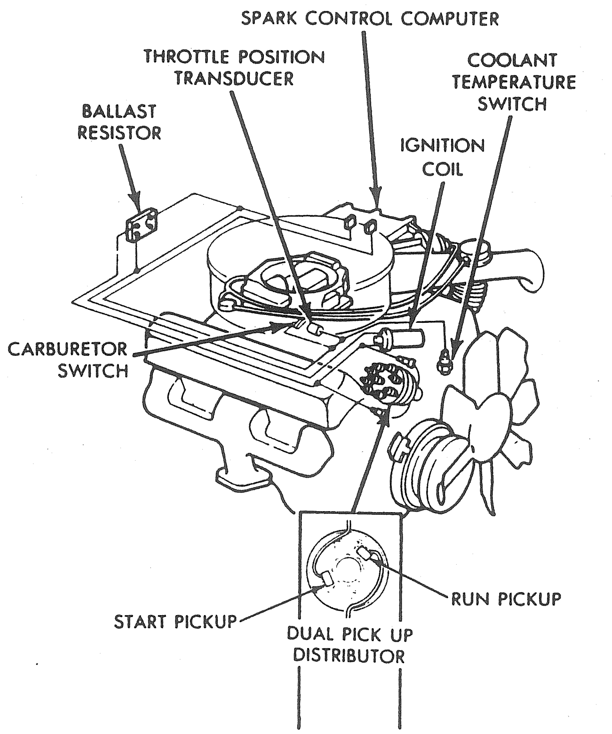


FIGURE 8-16
Electronic lean burn system. (Courtesy of Chrysler Motors Corp.)

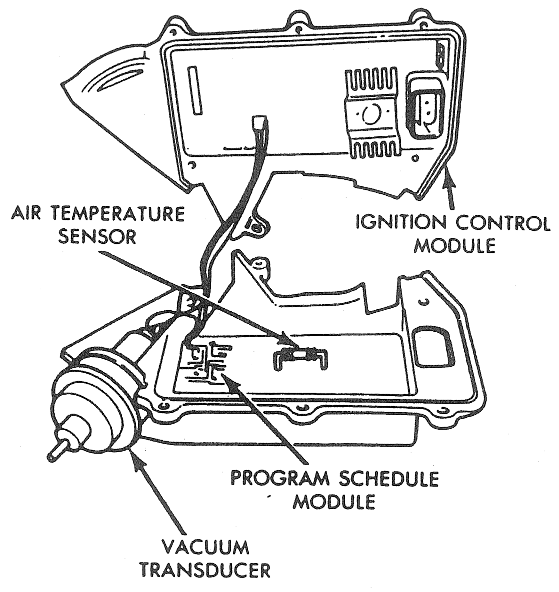


FIGURE 8-17
Spark control computer. (Courtesy of Chrysler Motors Corp.)

the distributor. After 1981, all 2.6-liter engines (except those with electronic fuel injection) use an ignitor mounted inside the distributor (see Fig. 8-15). To aid in properly cooling the ignitor, silicone grease is used between its lower side and the distributor housing.

The engines with electronic fuel injection have an externally mounted ignitor. This unit links the ignition system to a computer-controlled, fuel injection system.

8-5 CHRYSLER ELECTRONIC LEAN BURN SYSTEM

Chrysler introduced the electronic lean burn (ELB) system in 1976 and used it through 1978 (Fig. 8-16). The purpose of the *electronic lean burn* system is to electronically provide the correct spark advance curves to ignite the lean air/fuel mixture. This lean mixture is necessary to lower harmful exhaust emissions and to increase fuel economy.

A lean mixture requires a tighter control on spark timing because it burns slower. This is due to the reduced density of a lean mixture; that is, there is a greater distance between the fuel particles.

The ELB system was the first electronic spark control used in the automotive industry. This device permits a more precise control of ignition spark timing than the conventional centrifugal and vacuum advance mechanisms can provide. By accurately controlling the spark timing, ELB reduces emission, improves engine performance, and increases fuel economy.

The ELB was first used in 1976 on the 400 CID engine. In 1977, Chrysler also installed it on vehicles with 360, 400, and 440 CID engines. Lastly, the ELB was installed on 1977 vehicles with 318 CID engines.

Spark Control Computer

The ELB system consists of a ballast resistor, computer, and seven sensors. The *spark control computer* mounts on the air cleaner housing (Fig. 8-17). This unit controls the operation of the primary coil circuit and provides a variable amount of advance curves. In the case of the 1976 ELB system, the computer supplements the centrifugal advance mechanism.

The analog computer controls the spark advance based on input from the seven sensors. To do this, the computer is made up of two electronic printed circuit boards, the program schedule module, and the ignition control module. In later computers, the two circuit boards are combined into a single unit.

Based on input from the seven sensors, the program schedule module determines the exact ignition timing required and then signals this information to the ignition control module. The ignition control module, after receiving the signal from the schedule module, interrupts the current flow in the primary windings. This results in the induction of high secondary voltage at the coil's high tension terminal at the precise moment it is needed for efficient spark timing.

The spark control computer assembly fastens into the system by means of a multi-pin connector. The female connectors slide and lock into receptacles beneath the spark control computer housing. Although the socket pins are not physically numbered, they have numerals assigned to them for identification purposes.

Vacuum Transducer

The ELB system uses two types of transducers, a vacuum and a throttle position. A *transducer* converts mechanical motion into an electrical signal through *reactance*, which is the amount of resistance in an alternating current circuit caused by self-inductance.

The *vacuum transducer* mounts onto the microcomputer (Fig. 8-18). This device provides a voltage signal to the microcomputer that reflects the engine's manifold vacuum. To accomplish this function, the transducer has a moveable metallic core that connects to a vacuum diaphragm. With this design, the metallic core moves back and forth with changes in engine vacuum inside a coil. The higher the manifold vacuum, the farther the diaphragm and core move toward the vacuum fitting. A low vacuum causes the core to move in the opposite direction.

The coil receives an AC reference voltage signal from the microcomputer. It then monitors the amount of voltage drop that occurs across the terminals as the diaphragm moves the core into or out of the coil. With a high vacuum, the voltage drop and reactance are lower, and the transducer signal is high. A low vacuum places the core more inside the coil to provide the opposite conditions—that is, a higher voltage drop and a higher reactance, plus a lower transducer signal. In any case, the microcomputer uses the signal to calculate the timing based on vacuum.

Throttle Position Transducer

The *throttle position transducer* has the same function as the vacuum unit but its core is activated by a piece of carburetor linkage. The transducer itself provides an electrical voltage signal to the computer. This signal relates to the throttle valve position within the carburetor.

The throttle transducer consists of a wire-wound resistor coil and a moveable metallic core (Fig. 8-19). The coil is inside a housing with a threaded section on one end. This is used not only to secure the housing to a bracket but also to adjust the transducer.

The metallic core attaches by the steel wire to the throttle valve lever. With this arrangement, as the throttle valve opens, the core is pulled outward from the transducer housing. Consequently, when the throttle valve opens and closes, the transducer varies its voltage signal to the computer. Using this signal, the computer can provide additional spark advance when the throttle valve begins to open until it reaches the wide-open position.

Carburetor Switch

The *carburetor switch* is part of the idle stop solenoid assembly that mounts to the base of the carburetor (Fig. 8-20). This switch informs the spark control computer when the throttle valve is in the closed position. The switch performs this task by grounding the vacuum transducer electrical circuit. This action cancels any spark advancement when the engine is idling.

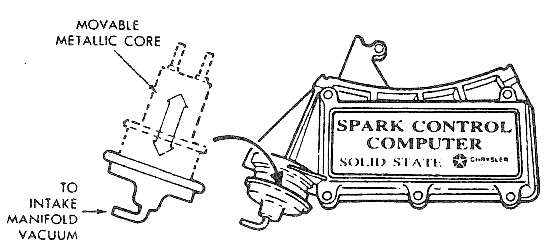


FIGURE 8-18
Vacuum transducer. (Courtesy of Chrysler Motors Corp.)

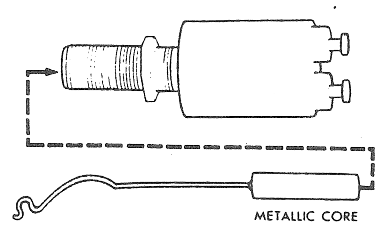


FIGURE 8-19
Throttle position transducer. (Courtesy of Chrysler Motors Corp.)

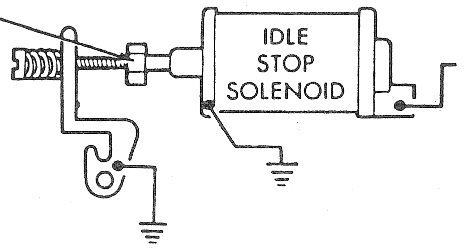


FIGURE 8-20
Carburetor switch. (Courtesy of Chrysler Motors Corp.)

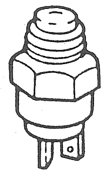


FIGURE 8-21
Coolant temperature switch. (Courtesy of Chrysler Motors Corp.)

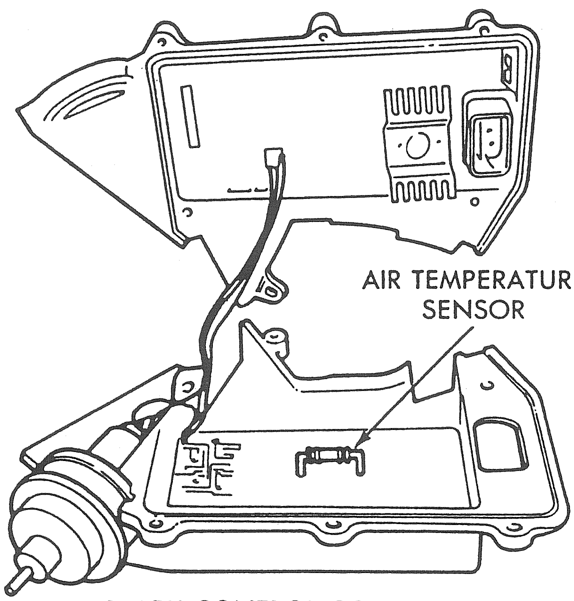


FIGURE 8-22
Air temperature sensor. (Courtesy of Chrysler Motors Corp.)

Coolant Temperature Sensor

The *coolant temperature sensor* supplies a ground circuit to the spark control computer (Fig. 8-21). It does so whenever the engine coolant temperature is below 150°F (65°C). The coolant switch is wired into the vacuum transducer electrical circuit inside the computer. When the coolant temperature is less than 150°F (65°C), regardless of the level of the intake manifold vacuum, the switch grounds out the transducer electrical circuit. As a result, there can be no additional spark advancement due to vacuum transducer action.

Air Temperature Sensor

The 1976 electronic lean burn (ELB) system has an *air temperature sensor* inside the spark control computer (Fig. 8-22). This sensor, also referred to as an ambient air sensor, develops a DC analog signal for the computer that is based on air temperature.

The sensor itself is a *thermistor*. A thermistor is made of a semiconductor material whose resistance changes inversely with temperature. Therefore, as the air temperature increases, the sensor's resistance decreases. This causes the sensor's output signal to increase.

The air temperature sensor operates in conjunction with the throttle transducer to control spark advance. The air temperature sensor controls the maximum allowable spark advance. If the air temperature sensor is hot, a smaller amount of advancement is allowed. On the other hand, if the sensor is cold, the computer will permit additional spark advancement.

Start-Pickup Coil Sensor

The ELB system uses two pickup coils within the distributor, the start and the run. The *start-pickup coil* controls the spark timing during engine starting (Fig. 8-23). The air gap between the start coil's metal core and its reluctor is less than that of the run-pickup coil. This small gap causes the start-pickup coil to produce a stronger signal as the reluctor turns slowly during engine starting. Moreover, during engine cranking, the spark timing is determined by the position of the start-pickup coil.

Run-Pickup Coil Sensor

The *run-pickup coil* produces a signal during all phases of engine operation. The run-pickup coil takes over when the computer senses increases in en-

gine speed and immediately overrides the start-pickup signal.

1977 ELB Modifications

There were two modifications to the 1977 ELB system. First, the air temperature sensor was taken out of the spark control computer. Second, the distributor no longer contained a centrifugal advance mechanism. With this last change, the spark control computer provided all spark timing advances based on engine speed and vacuum, as long as the carburetor switch was open.

1978 ELB Modifications

There were a number of alterations to the ELB system of 1978 models. For example, a single ignition resistor replaced the dual type, and the spark control computer contained only a single printed circuit board (Fig. 8–24). In addition, the sensor source for the vacuum transducer was now a ported vacuum instead of a manifold vacuum.

Finally, the throttle position transducer has a 30-degree timing offset before beginning to advance the spark. By not allowing any spark advance from the throttle transducer until the throttle valve was opened more than 30 degrees helped to eliminate part-throttle spark knock.

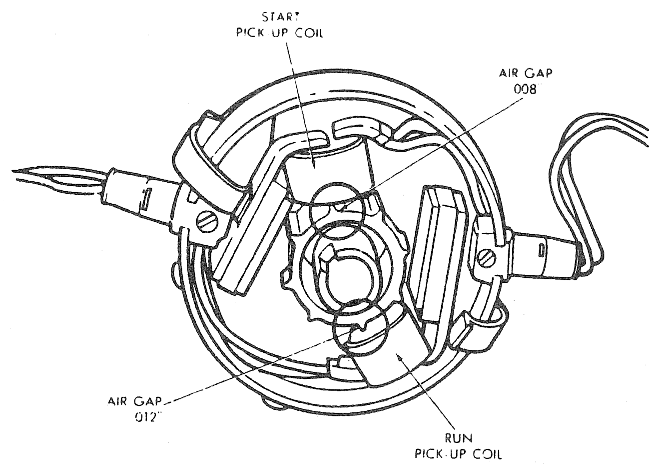


FIGURE 8–23
Start and run pickup coils. (Courtesy of Chrysler Motors Corp.)

8-6 ELECTRONIC LEAN BURN SYSTEM OPERATION

There are eight modes of operation in an ELB system: (1) initial start-up advance, (2) cold engine operation, (3) air temperature sensor advance, (4) vacuum transducer operation with a warm engine, (5) spark advance count-up, (6) spark advance count-down, (7) wide-open throttle advancement, and (8) limp-in operation.

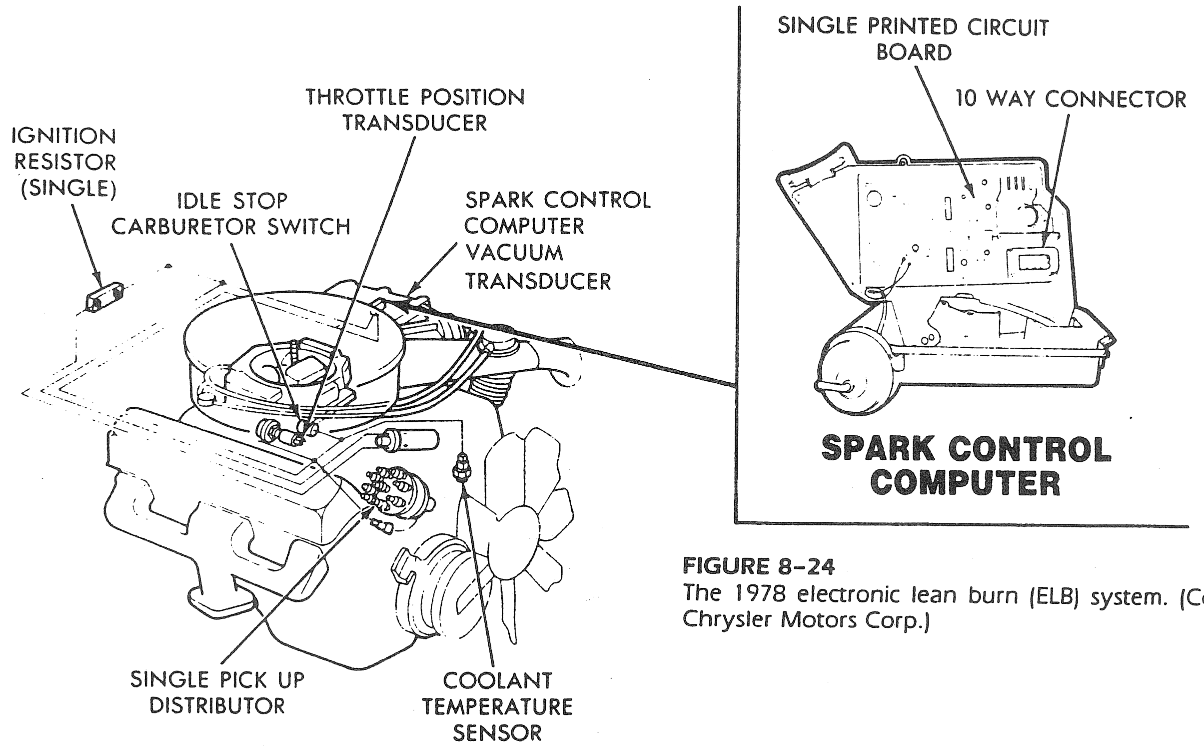


FIGURE 8–24
The 1978 electronic lean burn (ELB) system. (Courtesy of Chrysler Motors Corp.)

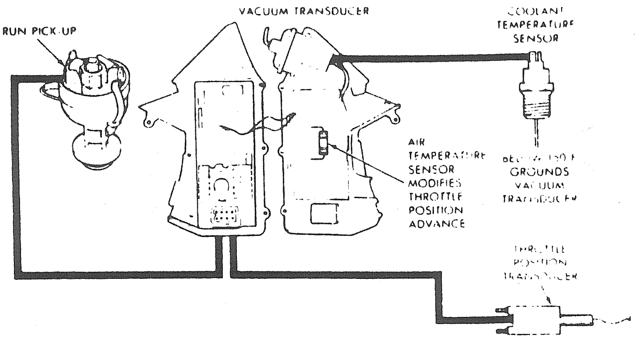


FIGURE 8–25
ELB system operation. (Courtesy of Chrysler Motors Corp.)

Initial Start-Up Advance

Once the engine starts, the computer switches over to the run-pickup coil within the distributor. The computer then provides additional spark advance for about one-and-a-half minutes (Fig. 8–25). This action during warm-up stabilizes engine operation and reduces the chances of cold engine stalling. After this period of time, the computer begins to slowly cancel out the additional spark timing and returns the engine to its basic timing.

Cold Engine Operation

As long as engine temperature is below 150°F, (65°C), the coolant switch remains closed, which grounds out the vacuum transducer signal to the computer. Although the vacuum transducer signal is being grounded at this time, the throttle position transducer's signal to the computer is providing spark advancement. At part-throttle, for instance, the transducer signals the computer to provide about 5 degrees of spark advancement. While at wide-open throttle, the transducer signals the computer to provide 10 degrees to 12 degrees of advancement.

Air Temperature Sensor Advance

If the air temperature sensor monitors less than 75°F (23.8°C), the computer will only advance the spark about 10 degrees at wide-open throttle. When the air temperature reaches 105°F (40°C), the sensor signals the computer to provide only about half the advancement called for by the throttle position transducer. Lastly, at air temperatures of 140°F (60°C), there will be no spark advance resulting from throttle transducer action, regardless of throttle position.

Vacuum Transducer Operation with a Warm Engine

Once the engine reaches 150°F (65°C), the coolant temperature switch no longer grounds out the vacuum transducer signal to the computer. As a result, the computer can perform advance functions from the vacuum transducer signal once the throttle is opened and off idle.

Spark Advance Count-Up

For every minute the vacuum transducer receives 16 inches of vacuum or more with both the carburetor and coolant switches open, the spark control computer begins to advance the spark timing about 5 degrees (Fig. 8–26). This computer action is known as *count-up.* Under these conditions and after three minutes of operation, the spark timing will advance about 15 degrees. After seven to nine minutes, the timing will build up to the maximum of about 35 degrees, depending on the computer's program. However, as the vacuum applied to the transducer varies, the timing advance provided by the computer also changes.

Spark Advance Countdown

When the throttle closes, the carburetor switch contacts the curb-idle screw, which grounds out the vacuum transducer circuit. This cancels the advance provided through the vacuum transducer signal, and the engine returns to basic timing.

The amount of advancement previously built up is stored electronically within the computer. For every minute that the throttle remains closed, the memory of the built-up timing begins to count down about 10 degrees. After about three-and-a-half minutes of closed throttle operation, all the memory of spark advancement that is stored in the computer from the vacuum transducer signal is wiped out.

If the throttle opens once again, the vacuum transducer circuit is no longer grounded out. If the vacuum to the transducer is over 16 inches, the computer will begin to count up and store spark advance data.

Wide-Open Throttle Operation

At wide-open throttle, the resulting low vacuum on the transducer causes the computer to cancel out the spark advance. This returns the engine to its base

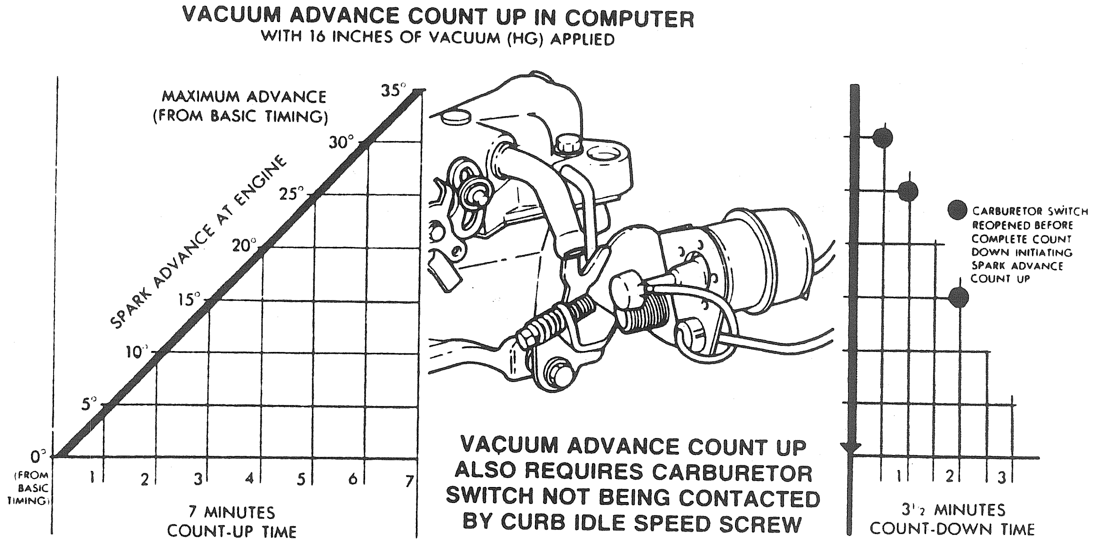


FIGURE 8–26
Spark advance count-up and countdown. (Courtesy of Chrysler Motors Corp.)

timing. However, in this case, the spark advance stored in computer memory remains intact until 16 inches or more vacuum returns to the transducer.

Limp-In Mode Operation

If there is a malfunction in the start-pickup coil or the ignition control module of the computer, the engine will not start or run. However, with a battery voltage below nine volts, or a malfunction of the vacuum transducer, run-pickup coil, or computer, the engine may run but will go into what is called the *limp-in mode*. In this situation, the system operates at the basic timing with resulting poor performance and fuel economy.

Four-Cylinder ELB System with Hall-effect Distributor

Beginning in 1978, the front-wheel drive Horizon and Omni models used an ELB system with a Hall-effect distributor (Fig. 8–27). The spark control computer in this system does not mount on the air cleaner. Instead, its location is on the left-front fender side shield within the engine compartment, but it operates the system in much the same manner as the ELB system discussed earlier (Fig. 8–28).

The system utilizes five sensors: (1) a vacuum transducer, (2) a coolant switch, (3) a throttle position switch, (4) a carburetor switch, and (5) the Hall-effect sensor. A single ballast resistor with a resistance of 0.5 ohm is used to reduce voltage and current flow in the primary circuit. However, the resistor is bypassed during starting.

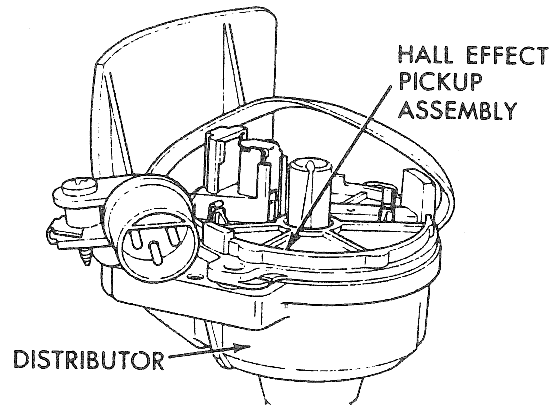


FIGURE 8–27
Hall-effect distributor. (Courtesy of Chrysler Motors Corp.)

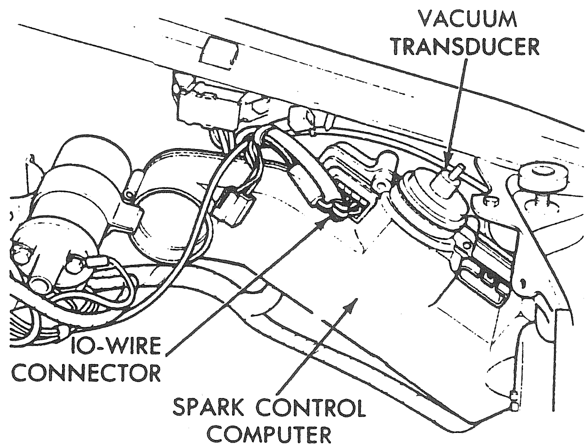


FIGURE 8–28
Location of the spark control computer. (Courtesy of Chrysler Motors Corp.)

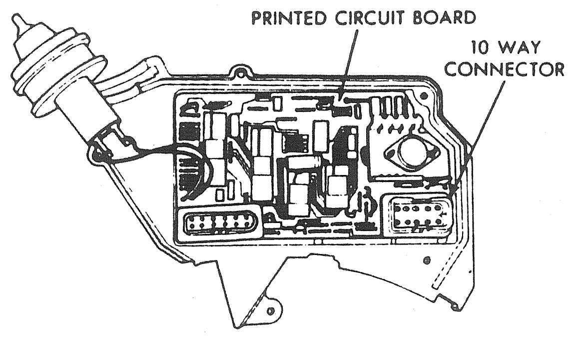


FIGURE 8-29
Digital electronic spark advance (ESA) computer. (Courtesy of Chrysler Motors Corp.)

8-7 ELECTRONIC SPARK CONTROL SYSTEM

For 1979 models, Chrysler introduced the *electronic spark control (ESC) system* that replaced ELB. The reason for this was the change from a lean air/fuel ratio of 18:1 to a richer 15:1 at cruise.

Six- and eight-cylinder engines equipped with ESC use magnetic pickup distributors. Four-cylinder models have Hall-effect distributors (see Fig. 8-27).

The ESC system is slightly different in some respects than ELB. For instance, ESC does not use a start-pickup coil sensor in magnetic impulse distributors. The throttle position transducer is eliminated in four-cylinder applications; on six- and eight-cylinder models, it has a 20-degree humped curve. The curve eliminates most of the advancement at wide-open throttle in order to reduce detonation or spark knock.

8-8 ELECTRONIC SPARK ADVANCE SYSTEM

In 1980, Chrysler introduced the *electronic spark advance (ESA) system.* This system is used in conjunction with a feedback carburetor, an oxygen sensor, and a combustion computer for closed loop fuel control. The ESA system uses a digital instead of an analog computer to improve performance and flexibility in programming (Fig. 8-29). The unit still mounts on the air cleaner except on four-cylinder engines and has a ten-way connector. Also, the system does not use a ballast resistor.

Distributor Types

As in the electronic spark control system, the electronic spark advance (ESA) system may use either a magnetic pickup or Hall-effect distributor. Six- and eight-cylinder engines use the former, while the four-cylinder models use the latter.

Computer Changes

The ESA computer is also different in several other ways from the electronic lean burn system. First, the ESA computer no longer provides the start-up advance mode for the first minute and a half. Second, due to the speed of this digital unit, the spark advance count-up and countdown are eliminated. The computer acts immediately to change spark timing according to sensor inputs.

Sensor Changes

The ESA does not use a throttle position transducer. The amount of spark advance is determined by the engine speed input signals from the run-pickup coil and vacuum transducer.

On California 318 and Federal 360 engines with 4V carburetors, the systems use a dual pickup coil distributor. This provides these configurations with better idle quality. But California six-cylinder engines use a single pickup distributor.

1981 ESA Modifications

The ESA system underwent several changes for the 1981 model year. For example, all engines used the dual pickup distributor except for electronic fuel injection (EFI) vehicles, which used a Hall-effect pickup.

A thermistor-type coolant sensor replaced the coolant temperature switch on some applications. This sensor is not a switch because its resistance changes with alterations in coolant temperature.

In four-cylinder applications, the computer provides a cold spark advance whenever the engine vacuum decreases and the engine is cold. This is the opposite reaction from normal operation, which is characterized by a decrease in spark advance with drops in the vacuum to the transducer. The cold spark advance helps improve cold driveability but is cancelled out when the engine reaches normal operating temperature.

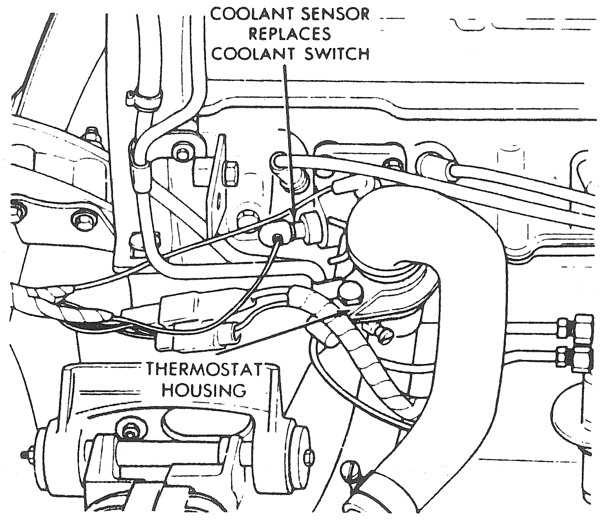


FIGURE 8-30
Coolant sensor. (Courtesy of Chrysler Motors Corp.)

1982 ESA Modifications

There were two modifications to the 1982 ESA system for four-cylinder engines. First, a coolant switch was used on all applications. Second, the distributor cap had a vent added to it.

1984 ESA Modification

There was one modification to the 1984 ESA system used on all four-cylinder models. The coolant switch was replaced by a thermistor-type coolant sensor (Fig. 8-30). The sensor controls the amount of timing advance during cold engine operation.

8-9 EFI SPARK CONTROL SYSTEM

In 1984 Chrysler began to use a redesigned electronic spark control systém (ESC) on its fuel-injected, 2.2-liter engines. The 2.2-liter system uses logic and power modules to control both the ignition and fuel injection systems.

Logic Module

The *logic module* contains a digital computer that processes the input signals from the various engine sensors. In turn, the logic module controls the ignition primary and fuel injection drive circuits from the power module (Fig. 8-31). The logic module also provides the memory for on-board diagnostics and initiates the limp-in mode. This module also supplies five volts to the manifold absolute pressure (MAP) sensor, and to the throttle position, coolant temperature, and charge temperature sensors.

The ignition portion of the system uses a Hall-effect distributor, MAP, and coolant temperature sensors for input signals to the logic module. The logic module monitors these signals to determine the proper spark advance, and supplies differing spark advancement schedules for cold and warm engine-operating conditions. Other sensor inputs such as vehicle speed, oxygen, and throttle position are used to control the fuel and other system operations.

The logic module is a separate unit from the power module. The logic module is inside the vehicle and behind the right-front kick pad.

Power Module

The *power module* is located in the left-front fender well behind the battery and has several functions. First, the power module supplies the ground for the ignition coil and fuel injection circuits, as directed by the logic module. Second, the power module supplies eight volts to the logic module and the Hall-effect pickup within the distributor.

Sensor Inputs

The *MAP sensor* is inside the vehicle and mounted above the logic module (see Fig. 8-31). In this system, the MAP sensor performs the same function as a vacuum transducer.

A hose connects the intake manifold vacuum to this sensor. The MAP sensor measures *manifold pressure,* which is a comparison of atmospheric pressure to the intake manifold vacuum. A low manifold vacuum indicates high manifold pressure, and a high vacuum means low pressure.

The logic module supplies five volts to the MAP sensor. As the vacuum is applied to the sensor diaphragm, the MAP output voltage changes in proportion to the vacuum signal's strength. For example, the approximate voltage output at zero vacuum (atmospheric pressure) is 4.9 volts. On the other hand, at maximum engine vacuum, the sensor output voltage may be as low as 0.3 volt.

The *coolant temperature sensor* is in the ther-

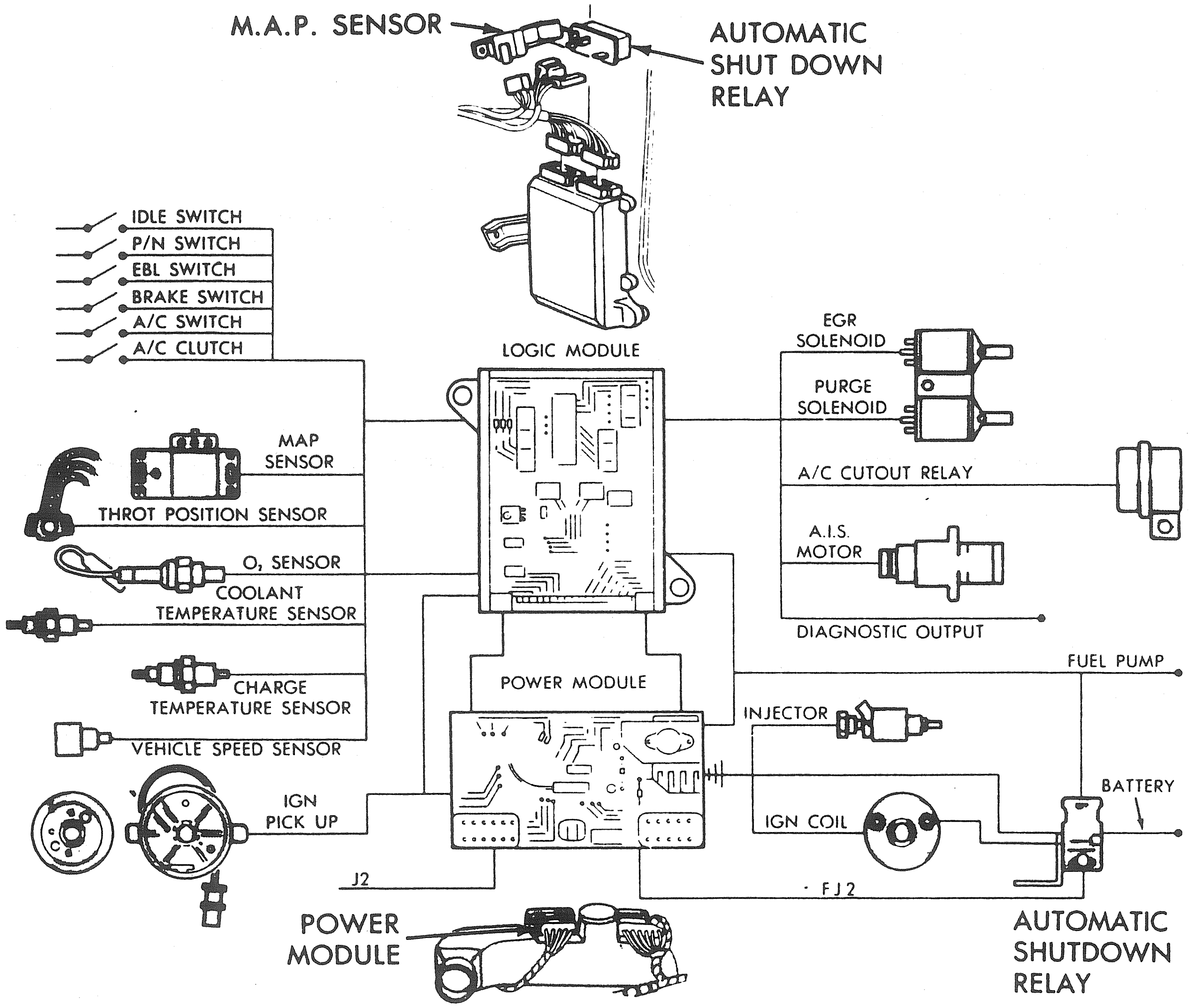


FIGURE 8-31
Electronically fuel-injected, electronic spark control system. (Courtesy of Chrysler Motors Corp.)

mostat housing. It monitors the engine coolant temperature. The sensor is a thermistor, so as the coolant's temperature increases, the resistance of the unit decreases. However, when the coolant temperature is low, the sensor resistance is higher. This causes a voltage drop across the sensor.

The five volts applied to the sensor by the logic module are therefore dropped by the sensor resistance to a lower value and then returned to the module. These sensor input signals are used to provide a cold engine spark advance in order to improve engine operation. As the engine warms up, the sensor input signal causes the computer to modify the spark advance.

The Hall-effect distributor provides a DC pulse signal to both the logic and power modules. The logic module uses the pulse signal to determine both engine rpm and piston position within the cylinder. The distributor pulse signal also determines the spark advance reference for the engine speed spark advance schedule. The logic module can then modify the spark advance as determined by the pulse signal and MAP sensor inputs.

The power module uses the distributor pulses to ground the *automatic shutdown relay* (see Fig. 8-31). Grounding of this relay allows it to supply battery voltage to the fuel pump, logic module, ignition coil (+) terminal, and the injector and ignition coil switching circuits within the power module.

The power module must receive the first distributor pulses for a minimum of one-half second at higher than 60 rpm. If it does not, the power module will shut down the fuel and ignition systems.

The automatic shutdown relay is inside the vehicle above the logic module. In 1985 models, the relay is built into the power module.

Chapter 9

TESTING TYPICAL CHRYSLER ELECTRONIC IGNITION SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- explain the precautions to be followed when testing Chrysler systems.
- describe how to test both the primary and secondary portions of a Chrysler electronic ignition system (EIS).
- explain the procedures for testing a Chrysler Hall-effect EIS.
- describe how to test a Chrysler electronic lean burn (ELB) system.
- describe how to test a Chrysler electronic fuel injected (EFI), electronic spark control system.

Since 1971, Chrysler Corporation has developed and used a number of electronic ignition and spark control systems for various applications. It would be impossible to discuss the testing procedures for all of them. To provide an introduction to the process, this chapter provides samplings of procedures used on the various systems covered in the last chapter. *Always follow the manufacturer's instructions, guides, and specifications when testing any system application in order to prevent damage to its many components.*

The following sections provide step-by-step electrical test procedures on system components. These steps are necessary to locate the cause of a no-start condition or poor performance, or are called for when a computer signals an ignition fault code.

9-1 GENERAL PRECAUTIONS AND TEST EQUIPMENT

Before learning to test Chrysler systems, you must review the general precautions for working on electronic ignition systems, in general, which are listed in the box below. In the box below are general precautions for working on Chrysler systems. Also, always observe the safety instructions outlined in Chapter 5.

General Precautions

The precautions and instructions listed below and on page 244 will not only save you time in locating the actual cause of a problem but prevent the possible destruction or replacement of an otherwise serviceable part.

Chrysler Systems

1. Always follow the emission label's specifications and test procedures over those found in a service manual.

2. Disconnect the ignition wiring harness connectors before conducting a compression test.

3. Make sure the ignition control module or computer is grounded properly before reconnecting the battery.

4. Do not file the teeth of the reluctor. They are designed to have sharp corners.

5. *Do not touch the transistor mounted on the ignition module with the engine running. The high voltage present in the transistor can cause a severe electrical shock.*

6. In the Hall-effect distributors, make sure the correct rotor is installed. It should have either a R × H, EIS, or A stamping.

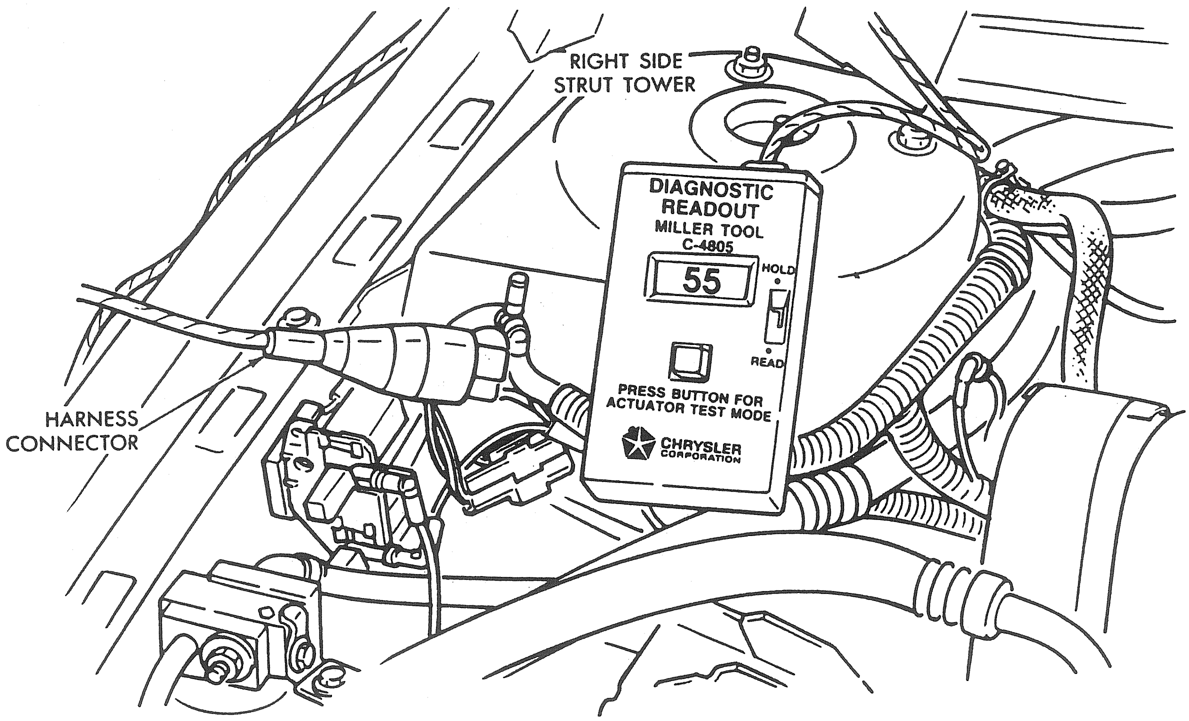


FIGURE 9-1
Diagnostic readout box. (Courtesy of Chrysler Motors Corp.)

7. A Hall-effect rotor must be seated and grounded properly on the distributor shaft.

8. Do not remove the multipurpose grease from the wiring connectors in the ignition system or pin junctions of the computer assembly. The grease is necessary in order to prevent moisture from corroding the terminals and to prevent electrical leakage between the pins.

9. There are no serviceable parts inside a computer or ignition module. If a unit is defective, it must be replaced as an assembly.

Test Equipment

Various pieces of test equipment are necessary to check the many types of Chrysler electronic ignition systems. Before you begin the ignition procedures that follow, be sure you have an accurate analog volt-ohmmeter, a power timing light with induction pickup, a spark tester, jumper leads, a nonmagnetic feeler gauge, and a vacuum pump tester.

Larger pieces of equipment necessary are an oscilloscope, module tester, and diagnostic readout box. The scope will be used to check the operation of both the primary and secondary circuits. A unit that is especially helpful is the Allen "Smart" scope because it is capable of reading distributor pickup coil signals. The module tester electronically checks the serviceability of the ignition module either on or off the vehicle.

The *diagnostic readout box* is used on the electronic fuel-injected (EFI), electronic spark control systems (Fig. 9-1). This box is not only used to read out the computer-stored fault codes but also to initiate an ignition system test sequence.

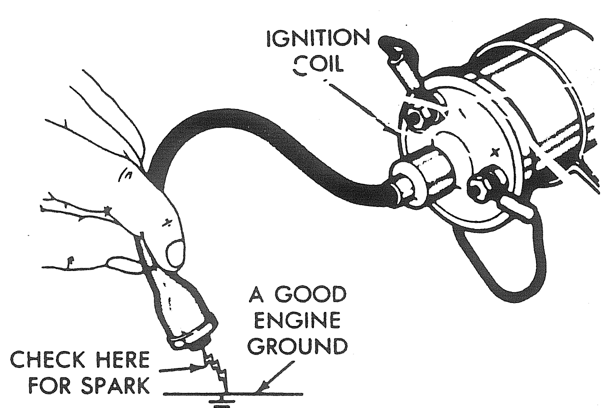


FIGURE 9-2
Coil output check. (Courtesy of Chrysler Motors Corp.)

9-2 TESTING A CHRYSLER ELECTRONIC IGNITION SYSTEM

If an engine with an electronic ignition system (EIS) will not start, troubleshoot the system for the cause of the problem by following the steps listed below.

Step 1—Coil Output Check

To determine if the coil is producing enough secondary voltage to bridge the spark plug gap, do the following:

1. Remove the coil's high tension wire and connect it to a spark tester, or disconnect the high tension wire and hold its end about 1/4 inch (6.35 mm) from a good ground (Fig. 9-2).

2. Have an assistant crank the engine over by means of the ignition switch. Observe the spark tester or wire end. If a crisp, bluish-white spark occurs, the coil is okay. In this case, check the cap and rotor for cracks, carbon tracking, and burned electrodes. Also, inspect the spring rotor terminal for lack of tension (Fig. 9-3).

3. If there is no spark or it is very weak, check the coil for cracks and arcing at the coil tower. If the coil is not cracked but arcing is present, use a towel to wipe the top of the coil off and check again. If arcing is still present, or the coil is cracked, replace it. Also, check the coil's high tension cable with an ohmmeter. If the wire is open or has excessive resistance, replace it. If the wire is satisfactory, proceed to Step 2.

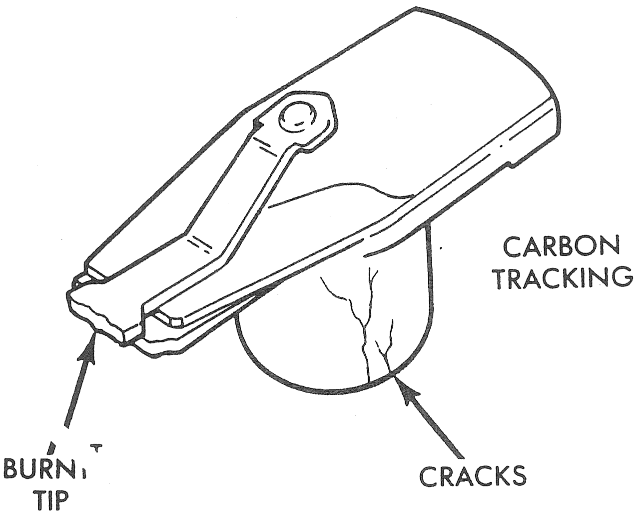


FIGURE 9-3
Rotor inspection. (Courtesy of Chrysler Motors Corp.)

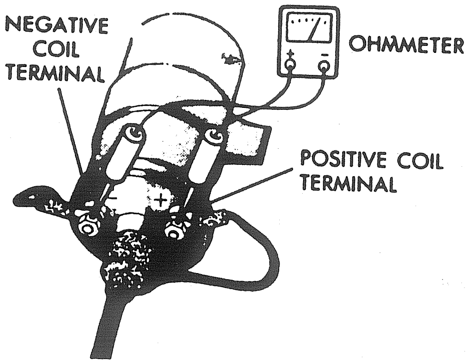


FIGURE 9-4
Primary resistance test. (Courtesy of Chrysler Motors Corp.)

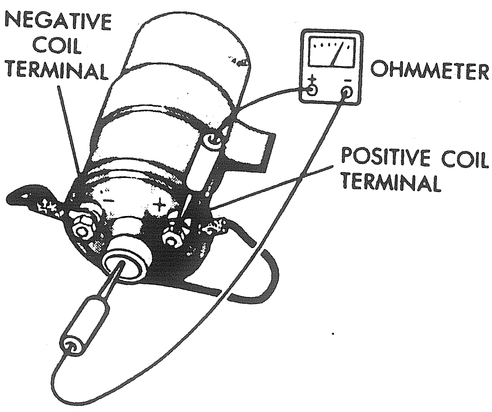


FIGURE 9-5
Secondary resistance test. (Courtesy of Chrysler Motors Corp.)

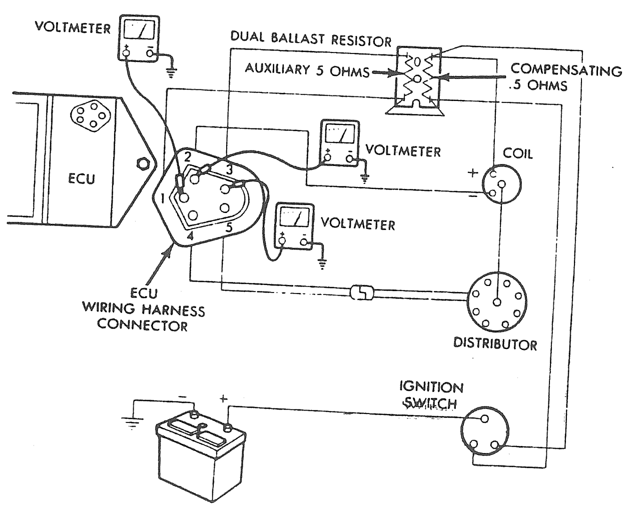


FIGURE 9-6
ECU harness voltage checks. (Courtesy of Chrysler Motors Corp.)

Step 2—Primary Resistance

To check the resistance of the primary windings against specifications, do the following:

1. Remove the wires from the primary (+) and (−) terminals.

2. Connect the leads of the ohmmeter to the terminals, as shown in Fig. 9-4, and read the resistance.

3. If the reading is to specifications, proceed to Step 3.

4. If the reading is not to specifications, replace the coil, and reconnect its primary wires.

Step 3—Secondary Resistance

To measure the resistance in the secondary coil windings, do the following:

1. Remove the high tension cable from the coil and both primary wires if it has not already been removed.

2. With the leads of the ohmmeter, measure the resistance between the high tension tower and the (+) primary terminal (Fig. 9-5).

3. If the reading is to specifications, reconnect the primary wires and high tension cable and proceed to Step 4.

4. If the reading was not to specifications, replace the coil.

Step 4—Voltage Tests at ECU Harness Connector

This test checks the voltage at harness connector locations against that of the battery. When performing the cavity tests, flex the wires at the connector.

1. With the voltmeter leads, measure, and record battery voltage.

2. With the ignition switch off, remove the wiring connector at the electronic control unit (ECU) (Fig. 9-6).

3. Turn the ignition switch on.

4. With the voltmeter leads, check the feed voltage between Cavity 1 and ground. The voltage should be within one volt of the battery reading. If

it is not, check the wiring harnesses and connectors from the ECU to the ignition switch. Also, test the ignition switch for an opening or high resistance. Repair or replace any defective component.

5. Check the voltage with the meter between Cavity 2 and ground. The reading should be within one volt of battery voltage. If it is not, check the ignition resistor, coil, connecting wires, and connectors.

6. With the meter leads, check the voltage at Cavity 3. The reading should be within one volt of battery voltage. If it is not, check the auxiliary side (five ohms) of the ballast resistor, wiring, and connectors between the resistor itself and the connector. If Cavities 1, 2, and 3 were okay, proceed to Step 5 or 6.

7. After finishing the test, turn the ignition switch off.

Step 5—Pickup Resistance Check

To measure the resistance within the pickup coil and for a grounded circuit, do the following:

1. With the leads of an ohmmeter, check the pickup resistance between Cavities 4 and 5 (Fig. 9-7). The resistance should be to specifications.

2. If the resistance is incorrect, disconnect the pickup coil connector at the distributor. Then, recheck the pickup coil resistance at the connector with the ohmmeter. If the resistance is still not to specifications, replace the pickup assembly. However, if the coil resistance is satisfactory, replace the harness between the pickup and the ECU connectors.

3. With the ohmmeter leads, check the resistance between Cavity 5 and ground, and then Cavity 4 and ground (see Fig. 9-7). The meter should read infinite resistance. If, on the other hand, continuity is indicated, replace the pickup assembly.

4. If the pickup coil checked out okay, go to Step 7.

5. Plug in the pickup coil connector.

Step 6—Testing Coil Operation

This test can be used as an alternative to Step 5 if you have an Allen "Smart" scope or its equivalent. It will check the pickup coil operation with the en-

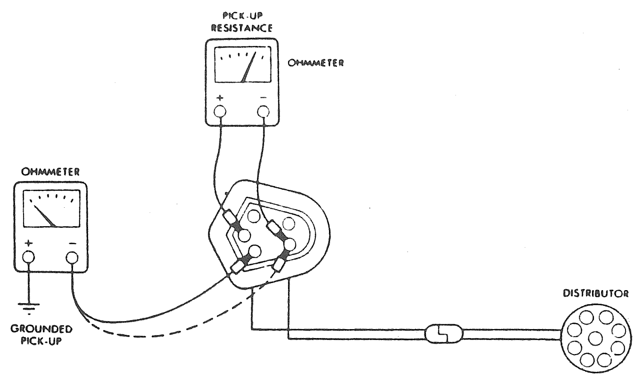


FIGURE 9-7
Pickup resistance and ground checks. (Courtesy of Chrysler Motors Corp.)

gine cranking over. To perform this test, do the following:

1. Disconnect the pickup coil harness connector.

2. Connect the red test probe to the male terminal of the pickup connector.

3. Attach the black test probe to the female terminal of the pickup connector.

4. Operate the scope in the self-sweep operating mode.

5. Place the ohm scale selector switch in the X10 position. The scope is now a 2.5 voltmeter using the left grid scale.

6. Crank the engine over using the ignition switch, while observing the scope screen.

7. If there is no scope pattern, replace the pickup coil.

8. If there is an AC sweep pattern, as shown in Fig. 9-8, the pickup coil is okay. Proceed to Step 7.

Step 7—Pickup Air Gap Check and Adjustment

To determine if the reluctor-to-pole-piece air gap is to specifications, do the following:

1. Remove the distributor cap.

2. Position a reluctor tooth exactly centered on the pole piece.

3. Measure the reluctor-to-pole-piece air gap with a nonmagnetic feeler gauge (Fig. 9-9).

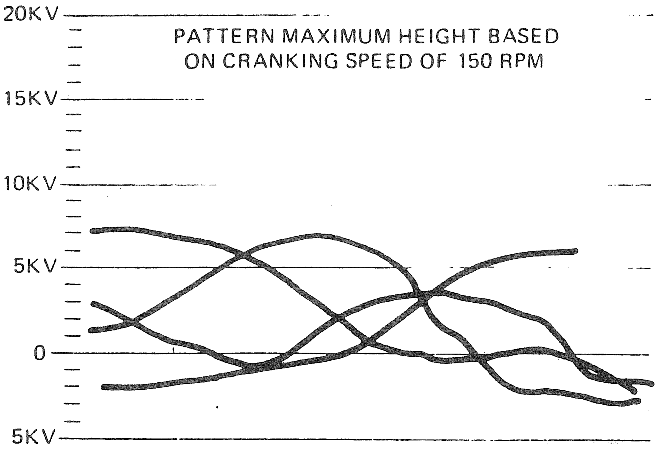


FIGURE 9-8
Testing pickup coil operation with a scope.

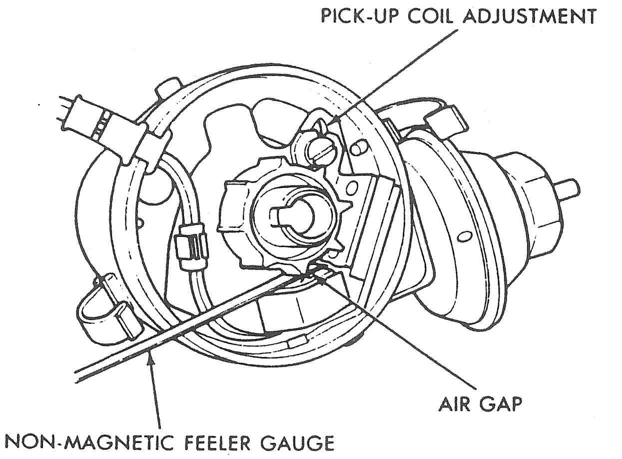


FIGURE 9-9
Checking pickup coil air gap. (Courtesy of Chrysler Motors Corp.)

4. If the air gap is to specifications, proceed to Step 8.

5. If the air gap is not to specifications, adjust it by loosening the pickup coil assembly holddown screw (Fig. 9-10) and inserting the correct thickness feeler gauge between the reluctor tooth and pole piece. Move the pole piece and coil assembly until it just contacts the gauge. Then, tighten the holddown screw. There should now be no clearance present between the feeler gauge and the reluctor tooth and pole piece. If there is, readjust the pickup assembly.

6. Rotate the reluctor and make a clearance check on several other teeth. If the clearance changes, either the reluctor tooth or the distributor shaft bushing is worn. Replace worn or defective parts.

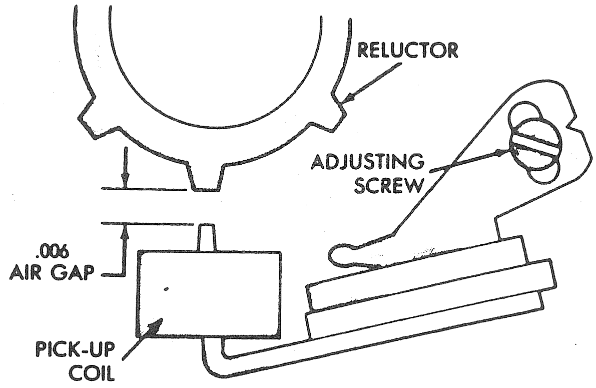


FIGURE 9-10
Adjusting pickup coil air gap. (Courtesy of Chrysler Motors Corp.)

7. If the pickup coil air gap is satisfactory, go to Step 8.

8. Reinstall the distributor cap.

Step 8—ECU Ground Check

To check the ECU grounding circuit, do the following:

1. With the ohmmeter leads, check the continuity between Pin 5 of the ECU and ground (Fig. 9-11).

2. If the meter indicates no continuity, remove the ECU attaching bolts and clean the module mounting surfaces.

3. Reinstall the bolts and recheck for continuity with the ohmmeter.

4. If continuity is still not present, replace the ECU. If you have a module tester, check the unit before replacing it to verify the problem.

5. Plug in the ECU connector.

Primary and Secondary Circuit Scope Tests

Primary and secondary scope analysis is the best way to quickly determine the cause of poor performance caused by a problem in the primary or secondary circuit. Figure 9-12 shows a comparison between the ideal primary pattern for a standard ignition system and the electronic ignition system (EIS).

Note in the illustration that the EIS primary pattern has fewer and smaller oscillations in the fir-

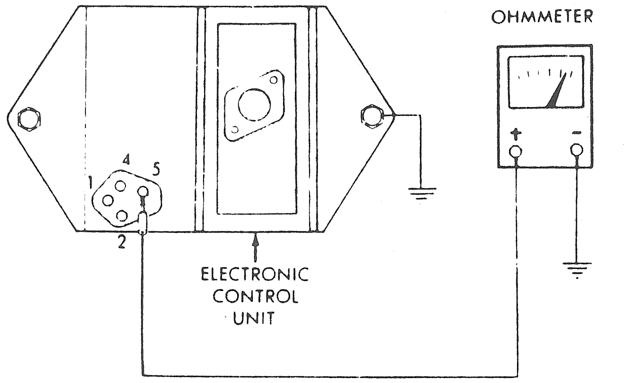


FIGURE 9–11
Checking the ECU ground. (Courtesy of Chrysler Motors Corp.)

ing section as compared to the standard system. Moreover, the EIS has no intermediate section. Therefore, as soon as the spark extinguishes, the power transistor in the ECU turns on again due to a positive pickup coil signal. This allows current to flow in the primary windings. Finally, at the end of the dwell section that is fixed and does not change, the transistor turns off the primary current flow as the ECU receives a positive zero signal from the pickup coil.

If there is any deviation from this primary EIS pattern, you can use any or all of the primary circuit tests just outlined to locate the cause of the problem.

Figure 9–13 shows a comparison of a standard to an EIS secondary pattern. Note also in the secondary the absence of the intermediate section. Once the spark extinguishes, the transistor turns on. The oscillations present when the transistor turns on represent the remaining voltage in the secondary windings that are dissipating as the current begins to flow in the primary circuit.

If there is any deviation from the transistor on and off signal, the cause can be found using the primary circuit tests outlined earlier in this section. Causes of malfunctions in the firing and spark lines can be diagnosed in the same way as outlined in Chapter 7, Section 7-2, Step 4.

9-3 TESTING A HALL-EFFECT EIS

If an engine with a Hall-effect EIS will not start, complete the secondary voltage test outlined under Section 9-1, Step 1. If the system fails this test, proceed with the primary voltage and continuity checks listed below.

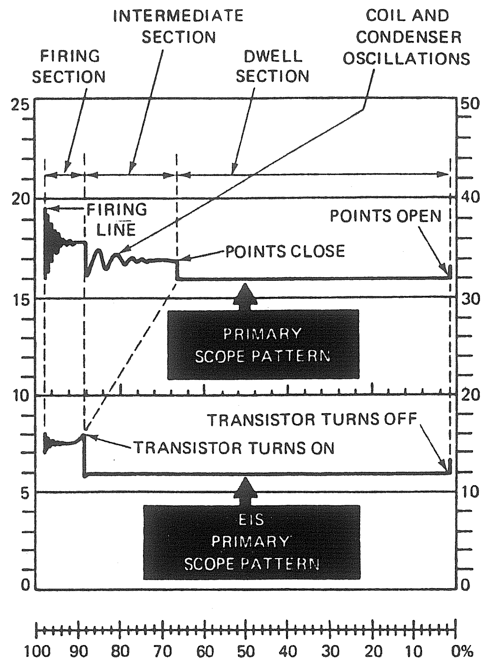


FIGURE 9–12
Primary EIS scope pattern. (Courtesy of Chrysler Motors Corp.)

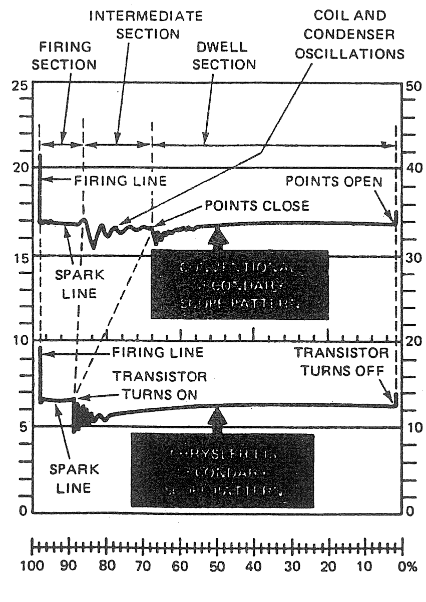


FIGURE 9–13
Secondary EIS scope pattern. (Courtesy of Chrysler Motors Corp.)

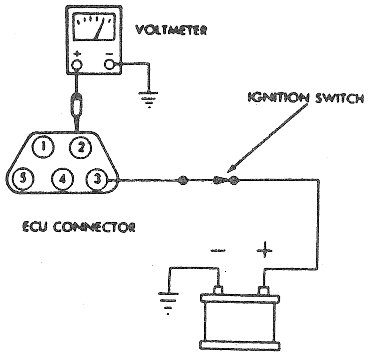


FIGURE 9-14
Checking Cavity 2 voltage. (Courtesy of Chrysler Motors Corp.)

Step 1—Cavity 2 Voltage Check

To test the voltage at Cavity 2 of the ECU connector harness against that of the battery, flex the wires at the connector and do the following:

1. With the voltmeter leads, measure and record battery voltage.

2. With the ignition switch off, remove the wiring connector at the ECU.

3. With the voltmeter leads, check the voltage between Cavity 2 and ground. The voltage should be within one volt of the battery reading (Fig. 9-14).

4. If the voltage is not correct, check the ignition feed circuit for an open, loose connection or excessive resistance.

5. If the voltage reading is satisfactory, proceed to Step 2.

Step 2—Cavity 5 Voltage Test

To check the voltage at Cavity 5 of the ECU connector harness against that of the battery, do the following:

1. With the voltmeter leads, measure the voltage between the ECU connector Cavity 5 and ground (Fig. 9-15). The reading should be within one volt of battery voltage.

2. If the voltage is incorrect, check the wire from the connector to the (−) side of the coil and the resistance of the primary coil. Repair or replace any defective parts.

3. If the voltage reading is okay, proceed to Step 3.

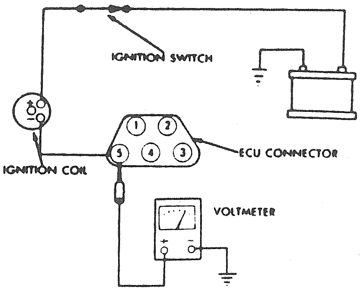


FIGURE 9-15
Testing Cavity 5 voltage. (Courtesy of Chrysler Motors Corp.)

Step 3—Distributor Connector Cavity 1 Voltage Test

To test the voltage of the distributor connector at Cavity 1 against that of the battery, do the following:

1. Turn off the ignition switch and assemble the harness connector to the ECU.

2. At the distributor, disconnect the wiring connector.

3. Turn the ignition switch on.

4. With the voltmeter leads, measure the voltage between the distributor harness Cavity 1 and ground (Fig. 9-16). The measurement should be within one volt of battery voltage.

5. If the voltage is not correct, use an ohmmeter to check the wiring harness for continuity between Cavity 1 of both the ECU and distributor connectors. If the harness has no continuity, repair or replace it. If the harness has continuity, replace the ECU. Before replacing the ECU, check it for serviceability with a module tester.

6. If the reading at Cavity 1 was okay, proceed to Step 4.

Step 4—Distributor Connector Cavity 2 Continuity Check

To check the continuity of the circuit between Cavity 2 and ground, do the following:

1. With the ignition switch off, use the ohmmeter leads to check for continuity between the distributor connector Cavity 2 and ground (Fig. 9-17).

2. If there is no continuity, proceed to Step 5.

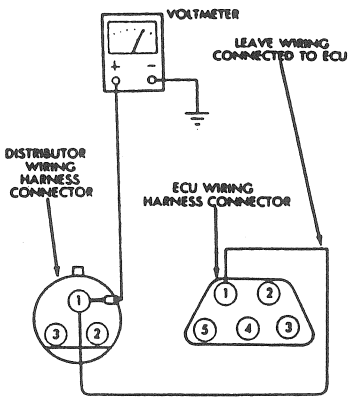


FIGURE 9-16
Checking distributor connector Cavity 1 voltage. (Courtesy of Chrysler Motors Corp.)

3. If the meter indicates continuity, check the wiring harness between the connectors for ECU Pin 4 and the distributor Pin 2 for an open circuit. Repair or replace the harness as necessary.

Step 5—ECU Continuity Check

To make sure there is continuity between ECU Pin 4 and ground, do the following :

1. With the leads of an ohmmeter, check for continuity between the ECU Pin 4 and ground (Fig. 9-18).

2. If there is no continuity, remove the ECU to make sure its mounting surfaces are clean. Recheck for continuity. If the test is again unsatisfactory, replace the ECU. However, check the ECU on a module tester before condemning the unit.

3. If the continuity was okay, proceed to Step 6.

Step 6—Hall-effect Pickup Test

To check the serviceability of the Hall-effect pickup within the distributor, do the following:

1. Reassemble the ECU connector but leave the distributor harness connectors separated.

2. Turn the ignition switch on.

3. Connect the coil's high tension wire to a spark tester.

4. While observing the spark tester, momentarily connect together with a jumper lead Cavities 2 and 3 in the distributor wiring harness connector (Fig. 9-19).

5. If a spark is produced, proceed to Step 7.

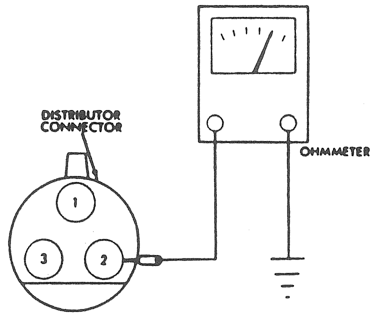


FIGURE 9-17
Testing distributor connector Cavity 2 voltage. (Courtesy of Chrysler Motors Corp.)

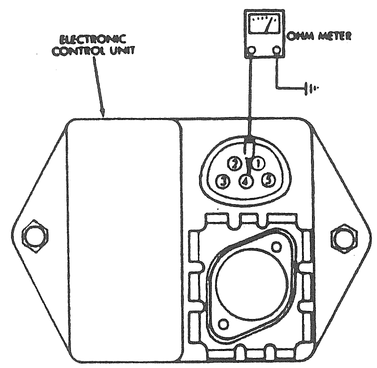


FIGURE 9-18
ECU ground test. (Courtesy of Chrysler Motors Corp.)

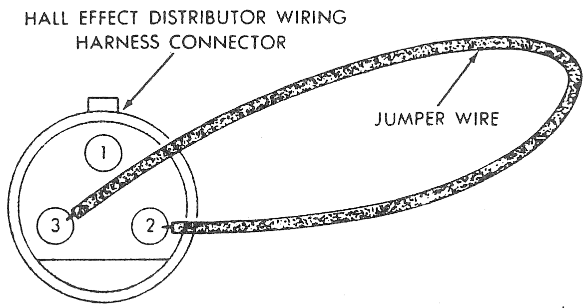


FIGURE 9-19
Shorting the distributor connector. (Courtesy of Chrysler Motors Corp.)

Step 7—Shutter Continuity Check

To test the continuity between the rotor shutters and ground, do the following:

1. Connect the leads of an ohmmeter between a shutter and a ground (Fig. 9-20). The meter should show continuity.

2. If there is continuity, replace the Hall-effect pickup.

3. If there is no continuity, push down on the rotor to seat it; perform the test again. If there is still no continuity, remove the rotor, scrape the in-

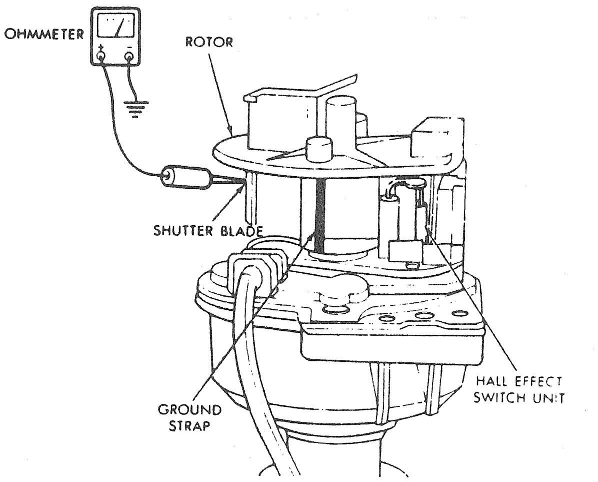


FIGURE 9-20
Shutter continuity check. (Courtesy of Chrysler Motors Corp.)

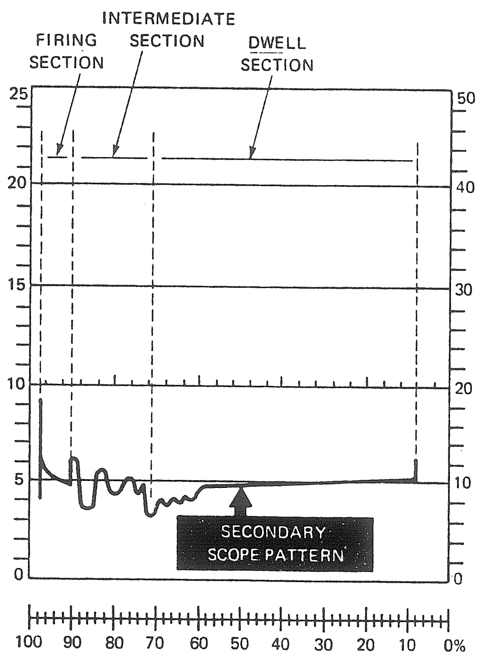


FIGURE 9-21
Hall-effect secondary pattern. (Courtesy of Chrysler Motors Corp.)

side of the shutter ground strap, and clean the spring contact grounding area of the shaft.

4. Repeat the continuity test. If there is still no continuity, replace the rotor.

Secondary Circuit Scope Tests

Scope testing the secondary pattern is the best way to quickly reveal the cause of most poor performance complaints. Figure 9-21 illustrates the secondary

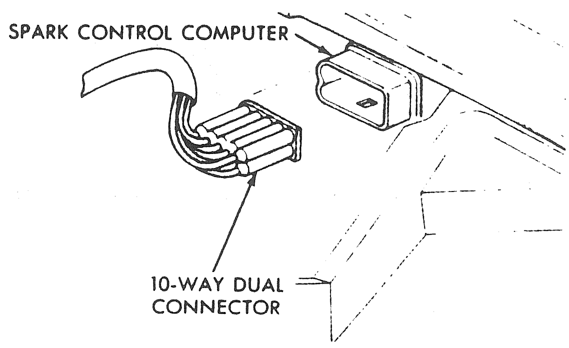


FIGURE 9-22
Separating the computer connector. (Courtesy of Chrysler Motors Corp.)

pattern for the Hall-effect EIS. Although the dwell in this system is also fixed, it does have an intermediate section.

If there is any deviation from the pattern shown in Fig. 9-21 within the intermediate and dwell sections, the cause can be found by performing the coil resistance checks or the primary circuit tests outlined in this section. Causes of malfunctions in the firing and spark lines can be diagnosed in the same way as outlined in Chapter 7, Section 7-2, Step 4.

9-4 TESTING AN ELECTRONIC LEAN BURN SYSTEM

If an engine with an electronic lean burn (ELB) system will not start, troubleshoot the system for the cause of the problem by following the steps listed below.

Step 1—Coil Output Check

To determine if the coil is producing enough secondary voltage to bridge the spark plug gap, do the following:

1. Remove the coil's high tension wire and connect it to a spark tester.

2. Have an assistant crank the engine over using the ignition switch.

3. Observe the spark tester. If a good spark is produced, check the resistance in the coil wire and rotor, cap, and coil, as outlined in Section 9-2, Step 1.

4. If there is no spark or it is weak, turn off the ignition switch and separate the dual connector from the bottom of the spark control computer (Fig. 9-22).

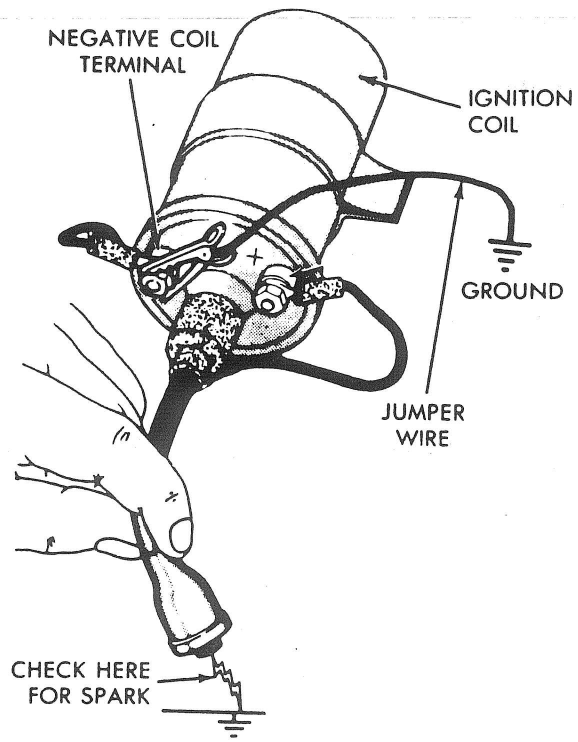


FIGURE 9-23
Performing a coil output check while grounding the negative coil terminal. (Courtesy of Chrysler Motors Corp.)

5. Turn the ignition switch on.

6. Intermittently short the primary coil (−) terminal to ground using a jumper lead (Fig. 9-23).

7. If a good spark now appears at the spark tester or when holding the coil wire 1/4 inch (6.35 mm) from ground, replace the spark control computer.

8. If there is no spark, perform the coil primary and secondary resistance tests as outlined in Section 9-2, Steps 2 and 3.

9. If the coil resistance is satisfactory, proceed to Step 2.

Step 2—Start Failure Voltage Test

To check the voltage at the carburetor switch, do the following:

1. Turn the ignition switch off.

2. Place a piece of cardboard or thick paper between the carburetor switch contact and the idle adjustment screw (Fig. 9-24).

3. Turn the ignition key on.

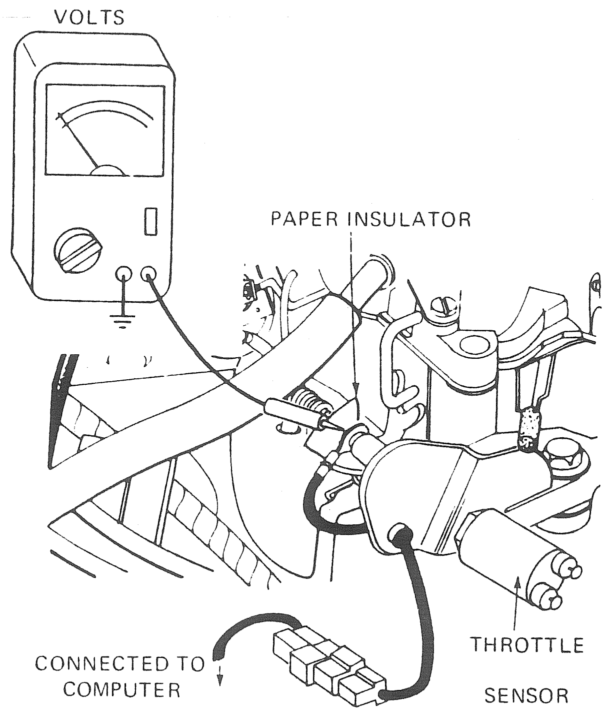


FIGURE 9-24
Checking the voltage at the carburetor switch.

4. Connect one voltmeter lead to a good ground and the other to the carburetor switch contact and check the reading.

5. If the reading obtained is between five volts and ten volts, go to Steps 4 and 6.

6. If the reading is less than five volts, proceed with Steps 3, 5, and 6, in that order.

7. If the reading is over ten volts, go to Step 6.

Step 3—Connector 2 Voltage Test

To check the level of voltage at the computer harness connector Terminal 2, do the following:

1. Turn off the ignition switch.

2. Unplug the ten-pin connector from the computer.

3. With the leads of a voltmeter, measure and record battery voltage.

4. Connect the positive (+) lead of the voltmeter to Terminal 2 of the connector (Fig. 9-25). Attach the negative (−) lead to a good engine ground.

5. Turn the ignition switch to the RUN position and read the voltage on the meter.

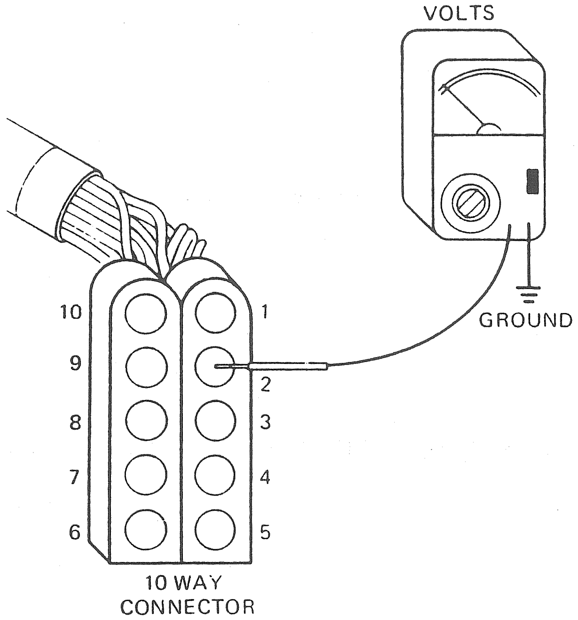


FIGURE 9-25
Testing the voltage at Terminal 2.

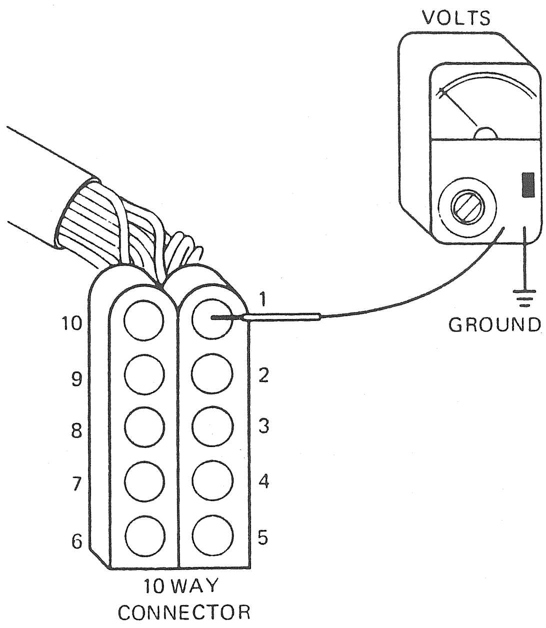


FIGURE 9-26
Checking the voltage at Terminal 1.

6. Turn the ignition switch off.

7. If the voltage is within one volt of that of the battery, go to Step 4.

8. If the reading is not within one volt of total battery voltage, check the wiring and connectors between Terminal 2 and the ignition switch. Repair or replace defective parts.

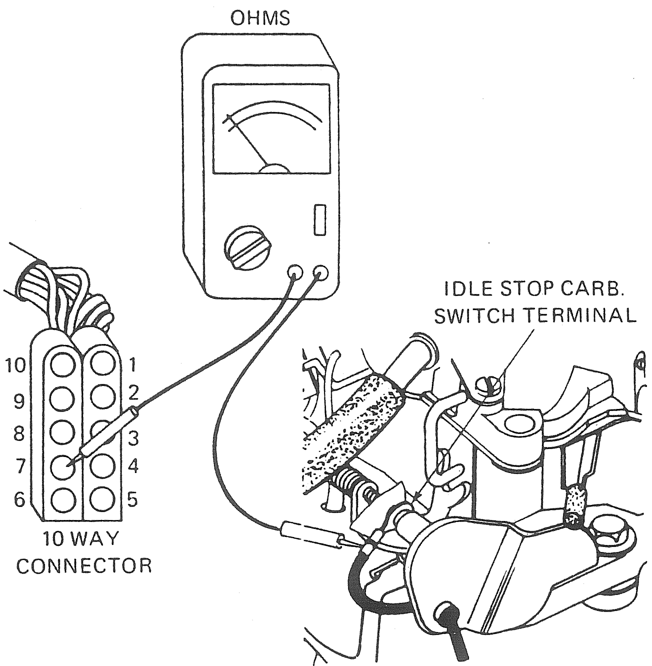


FIGURE 9-27
Testing Terminal 7 for continuity.

Step 4—Connector 1 Voltage Test

To measure the amount of voltage at Terminal 1 of the computer harness connector, do the following:

1. Attach the positive (+) voltmeter lead to the wiring connector Terminal 1.

2. Connect the negative (−) voltmeter lead to a good engine ground (Fig. 9-26).

3. Turn the ignition switch to the RUN position and read the voltage on the meter.

4. Turn the ignition switch off.

5. If the reading is within one volt of the total battery voltage, proceed to Step 5.

6. If the voltage is not within one volt of that of the battery, check the wiring and connector from Terminal 1 to the ignition switch. Repair or replace defective components.

Step 5—Terminal 7 Continuity Test

To check the continuity between Terminal 7 and the carburetor switch terminal, do the following:

1. Attach one ohmmeter lead to Terminal 7 inside the connector.

2. Connect the other ohmmeter lead to the terminal of the carburetor switch (Fig. 9-27).

3. Note the reading on the ohmmeter. If there is continuity, proceed to Step 6.

4. If there is no continuity, check the wire between the carburetor switch and Terminal 7 for openings, breaks, or shorts. Repair or replace the wire as necessary.

Step 6—Computer Ground Continuity Test

To check the continuity between Terminal 10 and ground, do the following:

1. Connect one ohmmeter lead to Terminal 10 inside the connector.

2. Attach the other ohmmeter lead to a good engine ground (Fig. 9-28).

3. Note the reading on the ohmmeter. If there is continuity, go to Step 7.

4. If there is no continuity, check the wires from Terminal 10 for any shorts, breaks, or poor connections. Make repairs or replacements as necessary. If the wires are satisfactory, replace the spark control computer.

Step 7—Ballast Resistor Test

To check the resistance within the ballast resistor against specifications, do the following:

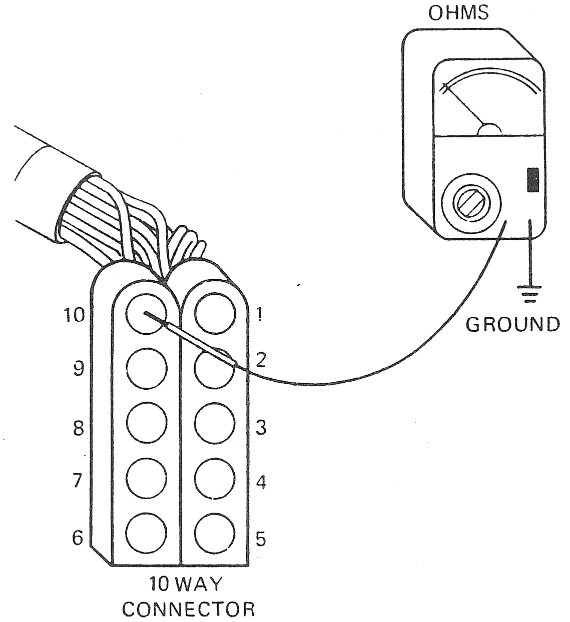


FIGURE 9-28
Computer ground continuity test.

1. Disconnect the wires attached to the ballast resistor.

2. Touch the ohmmeter leads to the resistor terminals and note the reading (Fig. 9-29).

3. If the resistance is to specifications, go to Step 8.

4. If the resistance is not to specifications, replace the ballast resistor.

Step 8—Pickup Coil Resistance Tests

To test the resistance in both the start- and run-pickup coils and to test for continuity of connector Terminals 3, 5, and 9, do the following:

1. Unplug both pickup coil connectors.

2. Touch one ohmmeter lead to each terminal of a pickup coil connector; read and note the resistance of the coil (Fig. 9-30). Wiggle the connector wires during the test.

3. Repeat the process on the other connector.

4. If the resistance is not to specifications, replace the affected pickup coil.

5. If both coil resistances are to specifications, plug in both the connectors.

6. Touch the ohmmeter leads to Terminals 5 and 9 inside the computer connector and check the resistance (Fig. 9-31). Note the reading.

7. Touch the ohmmeter leads to Terminal 3 and 9 inside the computer connector and check the resistance; note the reading.

8. If the readings are the same as those taken in 2 and 3 above, the wiring harness and connectors are satisfactory.

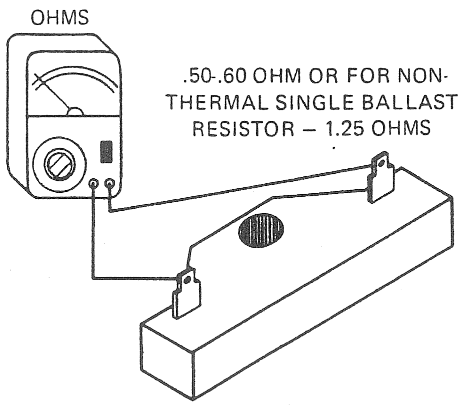


FIGURE 9-29
Ballast resistor check.

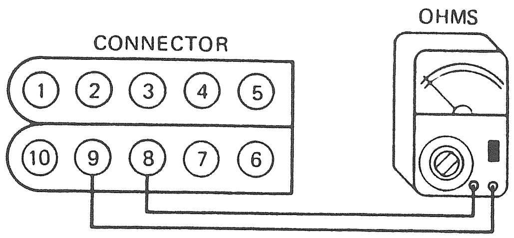


FIGURE 9-35
Testing resistance at Terminals 8 and 9.

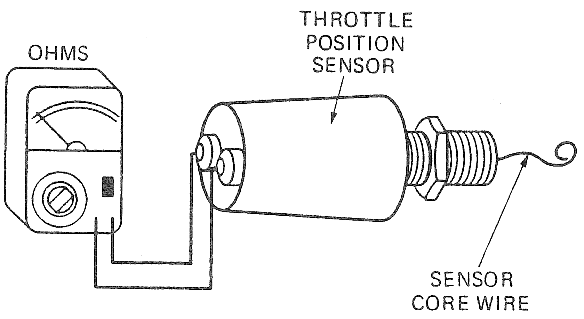


FIGURE 9-36
Checking resistance at the throttle position sensor terminals.

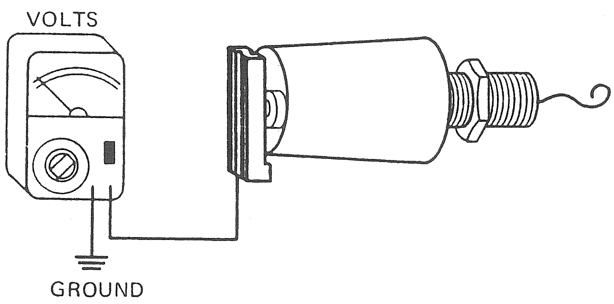


FIGURE 9-37
Testing throttle position sensor operation with a voltmeter.

tions, loosen the locknut. Rotate the sensor counterclockwise until the correct timing is reached, and then rotate another half turn. Tighten the locknut, shut the engine off, and remove the jumper wire.

8. If rotating the throttle position sensor has no effect on the timing, use the next procedure to test the sensor's serviceability.

Throttle Position Sensor Resistance Test

To check the serviceability of the throttle position sensor, measure the amount of its internal resistance by doing the following:

1. Remove the ten-pin connector from the spark control computer.

2. Touch the ohmmeter leads to Terminals 8 and 9 inside the connector (Fig. 9-35). Note the resistance.

3. If the resistance is not to specifications, remove the connector at the throttle position sensor. With the ohmmeter, test the resistance at the throttle position sensor terminals (Fig. 9-36). If the reading is now within specifications, repair or replace the wiring harness between the computer and the sensor.

4. If the resistance is still not within specifications, replace the throttle position sensor.

5. If the resistance was satisfactory, check the operation of the throttle position sensor with a voltmeter.

Throttle Position Sensor Operation

To check the serviceability of the throttle position sensor, determine its operating voltage at the terminals by doing the following:

1. Make sure all wiring harness connectors are correctly attached.

2. Turn the ignition switch to the RUN position, but do not start the engine.

3. Attach the negative (−) terminal of the voltmeter to ground.

4. Connect the positive (+) terminal of the voltmeter to one terminal of the throttle position sensor (Fig. 9-37). Do not disconnect the sensor from its wiring harness.

5. Watch the voltage readings as you open the throttle lever fully and then close it.

6. There should be a two-volt change at the terminal when the throttle opens and closes. If the voltage does not change, run the same test on the other sensor terminal. If the voltage change still does not occur, replace the throttle position sensor.

Coolant Temperature Sensor Resistance Test

To accurately measure the resistance of the coolant sensor, it must be tested with the engine both cold and hot. To make this check, do the following:

1. Disconnect the wiring from the sensor.

2. Connect one ohmmeter lead to a good ground (Fig. 9-38).

3. Touch the other ohmmeter lead to the terminal of the sensor that normally attaches to the black wire. Note the resistance against the cold sensor specifications.

4. Start and run the engine until it reaches normal operating temperature.

5. Again touch the ohmmeter lead to the terminal on the sensor that connects to the black wire. Note the resistance against the hot sensor specifications.

6. If the readings do not match the cold and hot specifications, replace the sensor.

7. If the sensor is serviceable and the spark advance is still not functioning according to specifications, replace the computer.

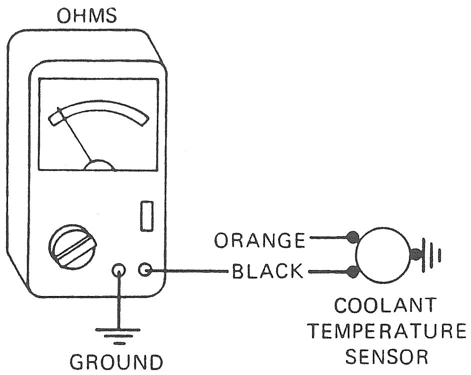


FIGURE 9-38
Testing the resistance of a coolant temperature sensor.

9-5 TESTING AN EFI SPARK CONTROL SYSTEM

The testing sequence presented below is for an engine no-start condition. The main difference between this test and the one previously provided is that it requires the use of a diagnostic readout box. As mentioned earlier, the readout box is used to show stored computer fault codes for problem diagnoses. However, its use in the sequence presented here will be limited to just initiating an ignition system test sequence and diagnosing its fault codes. Further use of this tool for fault code diagnosis of fuel and emission control systems is covered in a later chapter.

Step 1—Initial Setup and Test Sequence

If the engine will not start, install the readout box and run the ignition test sequence by doing the following:

1. Connect the readout box to the diagnostic connector located in the engine compartment near the right-side strut tower (Fig. 9-39).

2. Remove the cable from any spark plug and connect it to a spark tester.

3. While observing the tester, have an assistant crank the engine over.

4. If there is no spark, remove the coil's high tension wire from the distributor and connect it to the spark tester.

5. While observing the spark tester, press in the actuator test mode (ATM) button until Test Code 01 appears on the readout window.

6. Release the button. Three arcs should be produced at the spark tester. If these arcs do not appear, remove the coil's high tension cable and check its resistance with an ohmmeter.

7. If the cable resistance is satisfactory, position the READ/HOLD switch on the readout box in the READ position.

8. Turn the ignition switch on-off, on-off, and on within five seconds. Read and record all fault codes.

9. If the readout window displays the codes 88, 12, 55, go to Step 2.

10. If the readout window shows codes 88, 43, 55, proceed to Step 6.

11. Turn the ignition switch off.

Step 2—Checking the Voltage to the Ignition Coil Positive Terminal

To check the voltage from the power module to the coil (+) terminal, do the following:

1. Attach one voltmeter lead to ground.

2. Connect the other voltmeter lead to the primary (+) terminal (Fig. 9-40). Turn the ignition switch on.

3. Push in the ATM button until Test Code 01 appears in the readout window. Release the button.

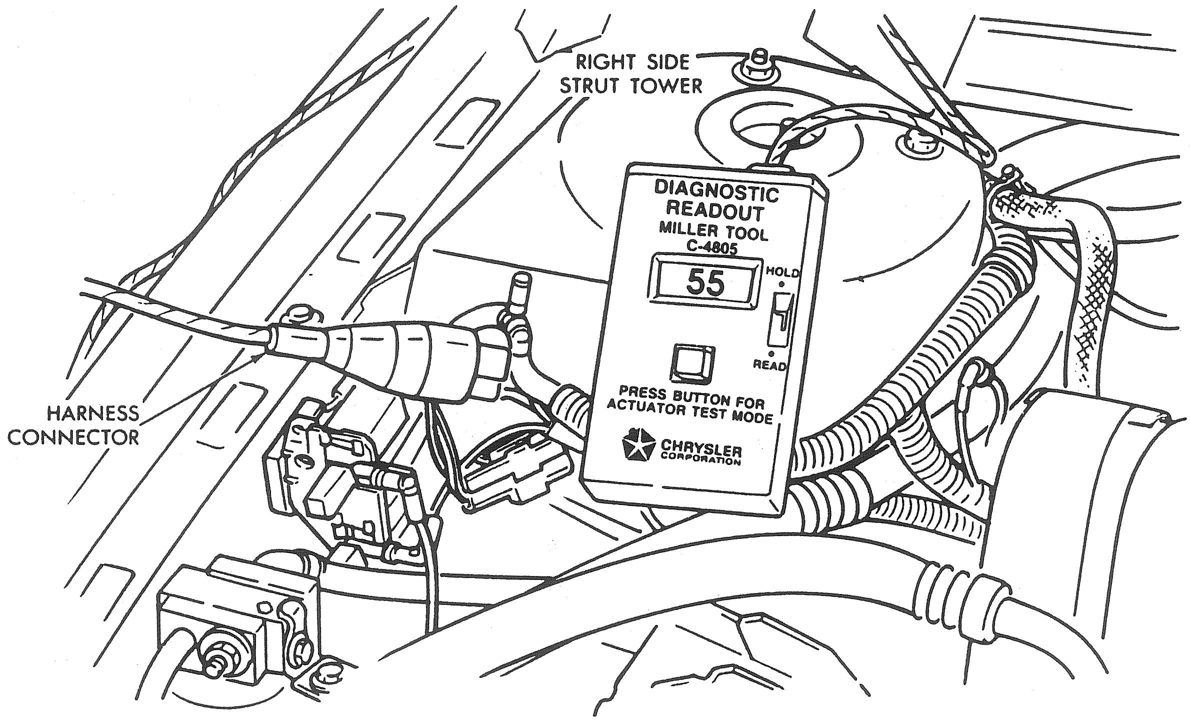


FIGURE 9–39
Installing the readout box. (Courtesy of Chrysler Motors Corp.)

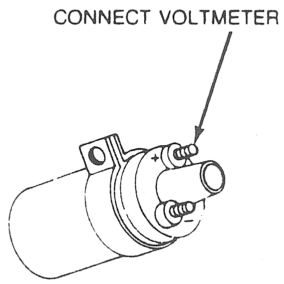


FIGURE 9–40
Testing the voltage to the coil (+) terminal. (Courtesy of Chrysler Motors Corp.)

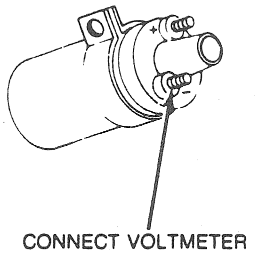


FIGURE 9–41
Checking the voltage to the coil (−) terminal. (Courtesy of Chrysler Motors Corp.)

The logic module will turn the ignition circuit on and off at two-second intervals for five minutes as long as the ignition switch is on.

4. Note the voltmeter reading. If the pulsating reading is within one volt of battery voltage, proceed to Step 3.

5. If the meter reads zero volts, check the wire to the power module for an open circuit. Repair or replace the wire as necessary.

6. Turn the ignition switch off.

Step 3—Testing the Voltage at the Coil Negative Terminal

To test the voltage at the coil (−) terminal against specifications, do the following:

1. Attach one voltmeter lead to ground.

2. Connect the other voltmeter lead to the (−) coil terminal (Fig. 9–41).

3. Turn the ignition switch on.

4. Push in the ATM button until Code 01 appears in the readout window; release the button.

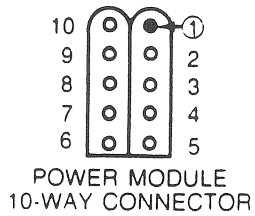


FIGURE 9–42
Testing the coil (–) wire for continuity. (Courtesy of Chrysler Motors Corp.)

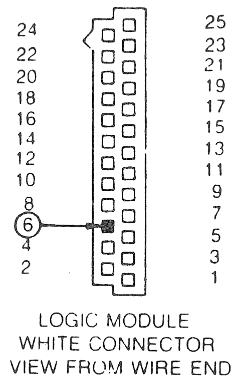


FIGURE 9–43
Checking the logic module spark control circuit. (Courtesy of Chrysler Motors Corp.)

5. Read the pulsating voltage on the meter; it should be one volt to three volts.

6. If the voltage is okay, replace the coil.

7. If the reading is within one volt of battery voltage, proceed to Step 4.

8. If the reading is from zero volts to one volt, go to Step 5.

9. Turn off the ignition switch.

Step 4—Checking the Ignition Coil Wire for an Opening

To check the continuity of the (–) coil wire to the power module, do the following:

1. Unplug the ten-way connector from the power module.

2. Connect one ohmmeter lead to the (–) coil terminal.

3. Touch the other ohmmeter lead to Cavity 1 of the ten-way connector (Fig. 9-42). Note the reading on the ohmmeter.

4. If the meter shows continuity, replace the power module.

Caution: Before replacing the power module, make sure the terminals in Cavity 1 are not so spread apart they cannot touch the power module pins.

5. If the meter indicates no continuity, repair the Cavity 1 wire for an open circuit.

Step 5—Testing the Ignition Coil Control Wire for a Short

To determine if there is a short to ground in the (–) coil wire to the power module, do the following:

1. Disconnect the wire from the (–) side of the coil.

2. Connect one voltmeter lead to ground.

3. Attach the other voltmeter lead to the (–) coil terminal.

4. Turn the ignition switch on.

5. Push in the ATM button until Code 01 appears on the readout window. Release the button.

6. Read the voltage on the meter. It should be pulsating and within one volt of total battery voltage.

7. If the voltage is satisfactory, check the ignition coil to the power module's Cavity 1 circuit for a short to ground. If the wire is not shorted, replace the power module.

8. If the voltage is not okay, replace the ignition coil.

9. Turn the ignition switch off.

Step 6—Checking the Spark Control Circuit

To test the spark control circuitry of the logic module, do the following:

1. Disconnect the coil's high tension cable from the distributor and attach it to a spark tester.

2. Unplug the white connector from the logic module, and connect one end of a jumper lead to Cavity 6 (Fig. 9-43).

3. Turn the ignition switch on.

4. Push in the ATM button until Code 01 appears on the readout window. Release the button.

5. While observing the spark tester, touch the other end of the jumper lead to a good engine ground. Make and break this connection several times. There should be an arc at the spark tester as you make and break the connection.

6. If the spark is satisfactory, replace the logic module.

Caution: Before replacing the logic module, make sure the terminal in Cavity 6 is not crushed so that it cannot contact the logic module pin.

7. If there was no spark, proceed to Step 7.

8. Turn the ignition switch off.

9. Reconnect the coil's high tension wire to the distributor.

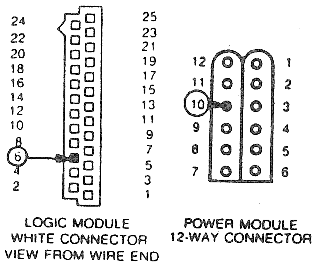


FIGURE 9–44
Testing the spark control wire for continuity. (Courtesy of Chrysler Motors Corp.)

Step 7—Testing the Spark Control Wire

To check the continuity of the spark control wire, do the following:

1. Remove the jumper wire from Cavity 6 of the white logic module connector.

2. Unplug the power module 12-way connector.

3. Attach one ohmmeter lead to Cavity 6 of the white logic module connector (Fig. 9-44).

4. Touch the other ohmmeter lead to Cavity 10 of the 12-way connector.

5. Check the ohmmeter reading; it should show continuity.

6. If there is continuity, replace the power module.

Caution: Before replacing the power module, make sure the terminals in Cavity 10 are not so spread apart they cannot touch the power module pin.

7. If there is no continuity, repair the wire from Cavity 10 of the 12-way connector to Cavity 6 of the logic module connector.

8. Plug in both the logic and power module connectors.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete the statement or questions, refer back to the section marked in brackets that covers the material.

SELF-CHECK

1. Explain the two functions of the diagnostic readout box with regard to ignition system testing [9-5].

2. For what reasons must you always follow the general precautions for working on ignition systems before testing a malfunctioning ignition system [9-1]?

3. Describe how to quickly determine if the spark control computer is the cause of no secondary voltage output [9-4].

4. Describe the color of the spark produced during a secondary voltage output check [9-2].

5. Explain how to perform a secondary voltage test on an electronic ignition system (EIS) and a Hall-effect EIS [9-3].

REVIEW

1. A vehicle with an electronic fuel injected, electronic spark control system will not start, and testing indicates there is no power to the coil.

What can be the cause of the problem [9-5]?
a. defective logic module
b. defective power module
c. defective starter relay
d. defective starter relay harness

2. If the timing specifications are different on the emission label and in a service manual, which should you use [9-1]?
Technician A says the service manual.
Technician B replies the emission label.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

3. The ATM button on the diagnostic readout box has what function(s) [9-5]?
Technician A states it initiates a test sequence.
Technician B says it initiates the fault codes.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

4. The first step in troubleshooting a malfunctioning ignition system is to [9-1]:
Technician A replies to check for loose or corroded connections.
Technician B states to check the battery state of charge.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

5. To use the readout box on the electronic fuel injected, electronic spark control system, plug its connector into the matching diagnostic connector located [9-5]
a. on the right-side of the passenger compartment.
b. on the right-side of the engine compartment near the strut tower.
c. both a and b.
d. neither a nor b.

6. An electronic lean burn (ELB) coolant sensor is checked by attaching the ohmmeter leads to what connection points [9-4]?
Technician A replies the orange and black wire terminals.
Technician B states the orange terminal and ground.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

7. What must be done before measuring primary and secondary coil winding resistance [9-2]?
a. Both primary wires must be removed.
b. The coil's high tension wire must be removed.
c. both a and b
d. neither a nor b

8. To check the serviceability of an ELB throttle position sensor, use a [9-4]
a. voltmeter.
b. ohmmeter.
c. diagnostic readout box.
d. both a and b.

9. When performing the electronic ignition system, electronic control unit (ECU) harness cavity checks, all readings must be within how much of battery voltage [9-2]?
Technician A replies two volts.
Technician B says six volts.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

10. The ELB resistor requires how many resistance tests [9-4]?
Technician A states one.
Technician B says two.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

11. The scope pattern for the pickup coil-type EIS system is missing what kind of section [9-2]?
a. firing
b. intermediate
c. dwell
d. spark

12. To perform a shutter ground check, use a (an) [9-3]
a. ohmmeter.
b. voltmeter.
c. scope.
d. ammeter.

13. The Hall-effect ECU has lost its ground. Where should you look for the cause of the problem [9-3]?
Technician A says at its mounting.
Technician B states inside the distributor.
Who is correct?
    a. A only
    b. B only
    c. both a and b
    d. neither a nor b

14. Reluctor teeth should have what kind of corners [9-1]?
    a. round
    b. square
    c. pointed
    d. sharp

15. If an engine will not start, which test do you perform first [9-3]?
    a. pickup coil resistance
    b. secondary voltage test
    c. shutter ground test
    d. ECU ground test

Chapter 10

GENERAL MOTORS ELECTRONIC IGNITION SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- explain the basic design of a high energy ignition (HEI) system.
- describe the operation of a distributor pulse generator.
- explain the function and design of an electronic spark timing (EST) system.
- describe the operation of an EST system.
- explain the function and design of an electronic spark control (ESC) system.
- describe the operation of an ESC system.
- explain the basic design of the distributorless ignition system (DIS).
- describe the operation of the DIS.

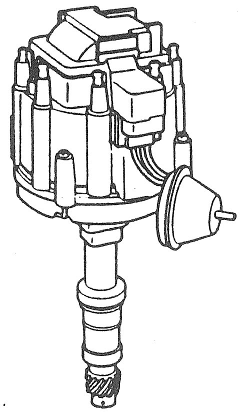


FIGURE 10-1
HEI distributor. (Courtesy of General Motors Corp.)

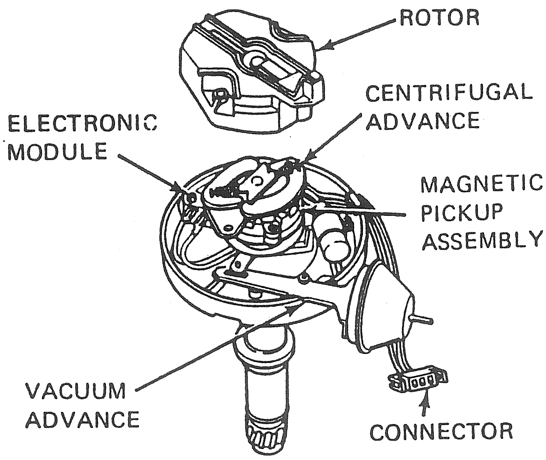


FIGURE 10-2
Lower housing components. (Courtesy of General Motors Corp.)

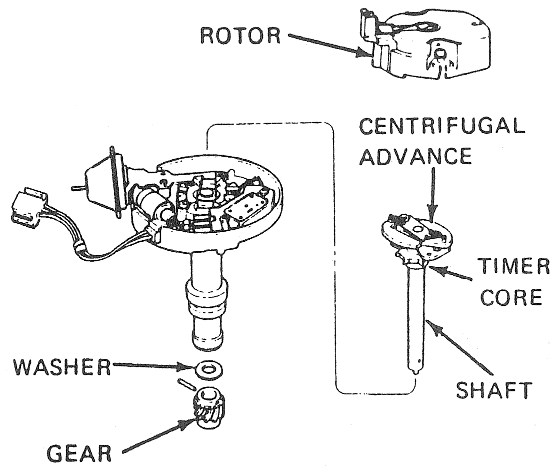


FIGURE 10-3
Distributor shaft assembly. (Courtesy of General Motors Corp.)

Before 1974, General Motors used three different types of electronic ignition systems as optional equipment. All of these systems (magnetic impulse ignition, capacitor discharge ignition, and unit ignition) improved engine performance and reduced the amount of system preventive maintenance. These systems are magnetically triggered, thereby eliminating contact points.

In early 1974, General Motors introduced the high energy ignition (HEI) system as optional equipment. By 1975, this system became standard equipment on all automobiles.

The HEI system provides a number of benefits over both the conventional contact point and early electronic systems. First, HEI requires no scheduled maintenance, so it meets the emission regulations dictating 50,000 miles of operation without a reduction in spark energy. Second, the system has up to 40 percent more voltage output and an 85 percent higher energy level than a contact point system. As a result, HEI produces up to 35,000 volts to ignite the lean air/fuel mixture of emission-controlled engines, even under the most adverse conditions. Finally, the higher voltage increases the useful life of spark plugs, especially when unleaded fuel is used.

10-1 DESIGN AND OPERATION OF THE HEI SYSTEM

The high energy ignition (HEI) system includes basically the same components as any conventional contact point system, including the battery, coil, ignition switch, and distributor. However, the physical arrangement and design of many of these parts have changed. For instance, this system does not require a resistance wire from the ignition switch to the coil, and there is only one wire from the distributor to the ignition switch. By and large, the major design change in the system is the distributor itself.

Distributor Design

In the HEI system, the ignition coil can be included within the distributor assembly rather than as a separate component (Fig. 10-1). The distributor is also larger to make room, in some models, for the coil and to prevent high-voltage arc over. Moreover, an integral pulse generator (magnetic pickup assembly) and control module more efficiently take the place of the conventional contact points.

Like a conventional distributor, the HEI unit contains two major assemblies, the lower housing

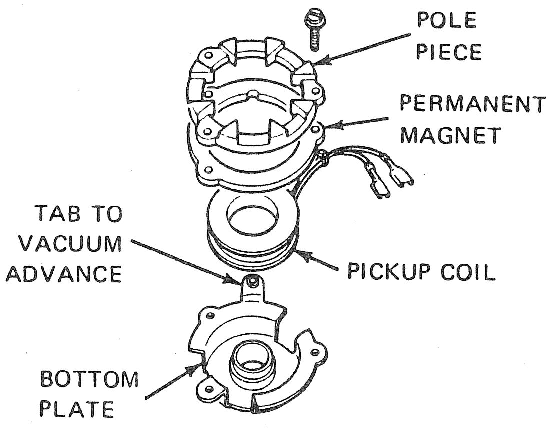


FIGURE 10-4
Design of the pulse generator. (Courtesy of General Motors Corp.)

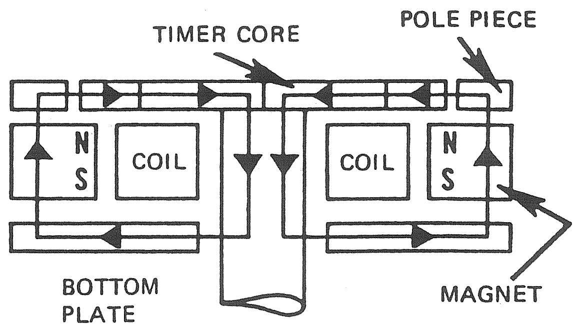


FIGURE 10-5
Magnetic circuit within the pickup coil assembly. (Courtesy of General Motors Corp.)

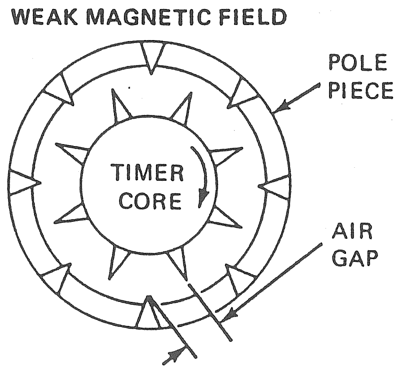


FIGURE 10-6
When the core and pole piece teeth are not in alignment, the magnetic field is weak. (Courtesy of General Motors Corp.)

and distributor cap. The lower housing assembly consists of the rotor, distributor shaft, magnetic pickup assembly, electronic module, centrifugal advance mechanism, vacuum advance unit, connector, and lower housing (Fig. 10-2). The rotor mounts by two screws to the centrifugal advance mechanism on top of the distributor drive shaft. In a similar manner as the rotor in a conventional system, this unit supplies secondary voltage from the coil to the distributor cap electrodes.

Figure 10-3 illustrates the components of the *distributor shaft assembly.* These include the shaft, gear, timer core, centrifugal advance assembly, and rotor.

The *timer core* is located on the distributor shaft where the breaker cam of a conventional system would normally be. In this location, the core rotates inside the magnetic pickup assembly. Also, the timer core incorporates the same number of teeth as the pole piece. These teeth provide a path for the magnetic field from the permanent magnet within the pulse generator.

Magnetic Pickup and Pole Piece

The *magnetic pickup and pole piece* (*the pulse generator*) produce a timed electrical pulse that is used by the switching transistor in the module to close and open the primary coil circuit. The assembly consists of a bottom plate, pickup coil, permanent magnet, and pole piece (Fig. 10-4). The bottom plate fits over a bushing that is installed in the distributor housing.

The *pickup coil* rests in a formed pocket within the bottom plate. The transistor triggering signal is induced in this unit by the changing magnetic field from the permanent magnet. The coil itself consists of a number of turns of fine, insulated wire, the ends of which attach to external harness connectors.

The pickup coil is sandwiched between a permanent magnet and the pole piece. The pole piece has a number of internal teeth, one for each cylinder of the engine. This assembly is then held in place by three screws that thread into the bottom plate.

Pulse Generator Operation

To understand how the pickup coil produces a pulse signal to the module, let's first examine the basic magnetic circuit and then see the influence on the field from the timer core (Fig. 10-5). In the pickup assembly, the permanent magnet provides a magnetic field that flows from the attached pole piece teeth, through the timer core teeth, and back to the permanent magnet. This field can pass through the pickup coil.

If the timer core and pole piece teeth are not aligned, the magnetic field strength is weak (Fig. 10-6). This is due to the enlarged area between the

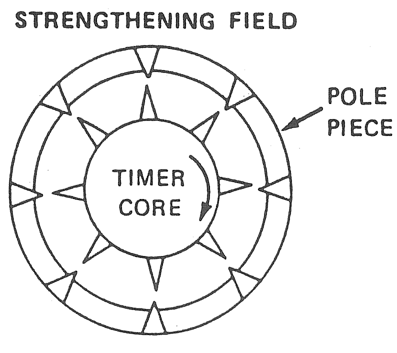


FIGURE 10-7
The magnetic field strength increases as the teeth move into alignment. (Courtesy of General Motors Corp.)

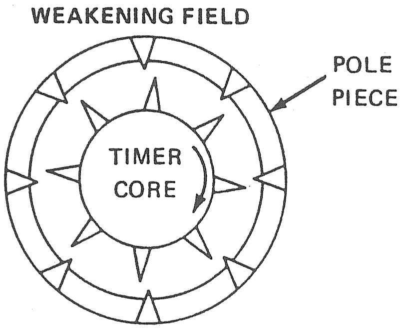


FIGURE 10-8
The magnetic field collapses as the teeth separate. (Courtesy of General Motors Corp.)

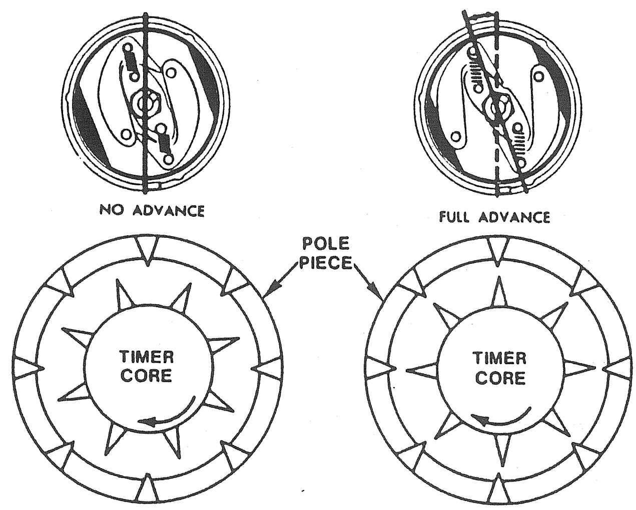


FIGURE 10-9
Centrifugal advance. (Courtesy of General Motors Corp.)

timer core and pole piece teeth, which produces a poor path for the magnetic lines of force.

When the timer core teeth approach alignment with those on the pole piece, the air gap becomes smaller (Fig. 10-7). As a result, the magnetic field becomes stronger. The increased field passes through the pickup coil and induces a positive voltage in the pickup coil in proportion to its strength. The positive signal is directed to the module to close the primary coil circuit.

The field strength continues to induce the positive voltage in the pickup coil until the teeth of the pole piece and timer core are in alignment. At this point, the magnetic field no longer is changing and the pickup coil voltage drops to positive zero. This positive zero signal is sent to the module and opens the primary coil circuit.

As soon as the timer core teeth pass those on the timer core, the air gap starts to increase (Fig. 10-8). As a result, the magnetic field collapses through the pickup coil. This action induces a voltage in the pickup coil that is negative in polarity.

The timer core, which turns with the distributor shaft, and the pole piece have the same number of teeth as the engine has cylinders. In the discussion so far, the distributor used is for a V-8 engine. Therefore, the timer core teeth align with those of the pole piece eight times for each rotation of the distributor shaft. As a result, the pickup coil produces eight timed AC voltage pulses to the module.

Centrifugal Advance

As mentioned, the HEI distributor has a *centrifugal advance mechanism* that operates above the timer core. This mechanism operates in much the same way as on the conventional contact point distributor.

In operation, the centrifugal advance weights move against spring tension as engine speed increases. The motion of the weights turns the timer core so that it rotates in the direction of the distributor shaft (Fig. 10-9). Consequently, the teeth of both the timer core and pole piece align sooner, signaling the module to advance the opening of the coil primary circuit. This, of course, has the effect of firing the air/fuel charge earlier in the engine cycle.

Vacuum Advance

The *vacuum advance assembly* bolts onto the outside of the lower distributor housing (see Fig. 10-3). This unit uses engine vacuum to move a spring-loaded diaphragm, which connects by a rod to a tab on the bottom plate of the pickup assembly (see Fig. 10-4). The pickup assembly mounts over the main bearing on the distributor housing, so it is able to rotate.

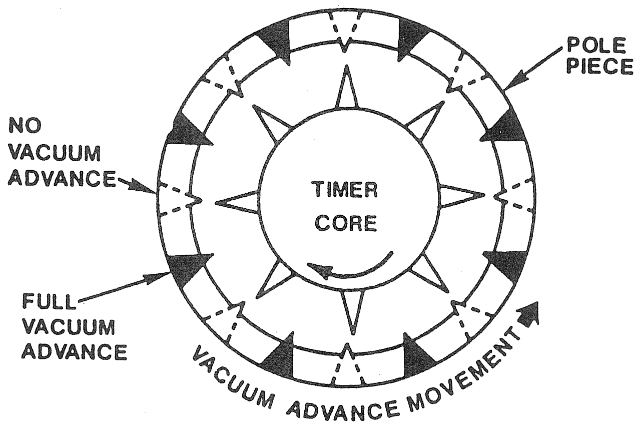


FIGURE 10-10
Vacuum advance. (Courtesy of General Motors Corp.)

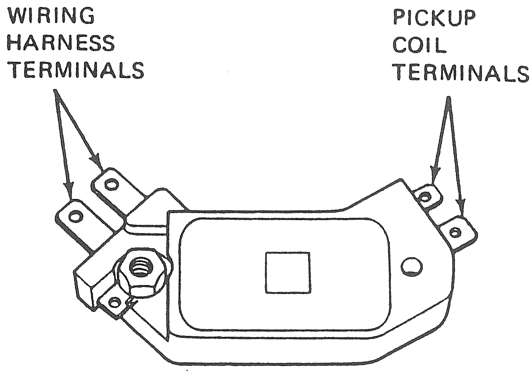


FIGURE 10-11
Electronic module. (Courtesy of General Motors Corp.)

Whenever a vacuum signal applies itself to the diaphragm, it, in turn, moves against spring pressure, pulling on the connecting rod. This movement causes the pickup assembly with its integral pole piece to rotate in an opposite direction from the distributor shaft and timer core (Fig. 10-10). As a result, the pole piece and timer core teeth align sooner, signaling the module to shut off primary coil current flow. This has the effect of firing the air/fuel charge earlier in the engine cycle.

Electronic Module

The *electronic module* has four terminals and bolts inside the lower distributor housing next to the magnetic pickup assembly (see Figs. 10-2 and 10-11). The module is responsible for actually closing and opening the primary coil circuit in response to signals from the pickup coil assembly. The module contains a microminiature electronic circuit with components so small that they cannot be seen even with a magnifying glass.

The module has no serviceable components and requires replacement when defective. When replacement is necessary, a special compound is required on the base of the module for proper heat transfer.

Module Signal

As mentioned, the pickup coil produces an AC signal to the module. The HEI electronic module is like any other microprocessor; that is, it will not function with alternating current. Therefore, the module contains a signal converter that changes the AC voltage to direct current (DC) that has a square wave (Fig. 10-12). The square wave DC signals are fed to the base circuit of the switching transistor to turn it and the ignition coil primary circuit either on or off.

Module Current-Limiting Circuit

In earlier systems, the transistor operated at a value less than its maximum capacity for protection from transient voltage and current extremes found in automobile circuitry. These extremes are usually of short duration but have great magnitude. Electromechanical devices such as switches, motors, and contacts can withstand these conditions without permanent damage.

However, transistors, if subjected to exposure to voltage and current above their maximum capability, will fail in a few milliseconds. The earlier systems had enough resistance so that the extremes mentioned above will always be within the capabilities of the electronic devices used to avoid failures. But this is the reason why there was no available secondary voltage gain in these systems.

To safely raise secondary voltage without damaging electronic components, the HEI module has a current-limiting circuit. Rather than using an external resistance wire, as mentioned earlier, the circuit itself limits primary current to 5.5 amperes. This allows the switching transistors to operate at their maximum value.

Dwell Control Circuit

For any ignition coil to produce its maximum secondary voltage, the primary current flow must reach its highest design value before the circuit is broken. In the contact point system, the length of time primary current flows is under the control of the breaker cam within the distributor. When the cam allows the points to close, primary current can flow.

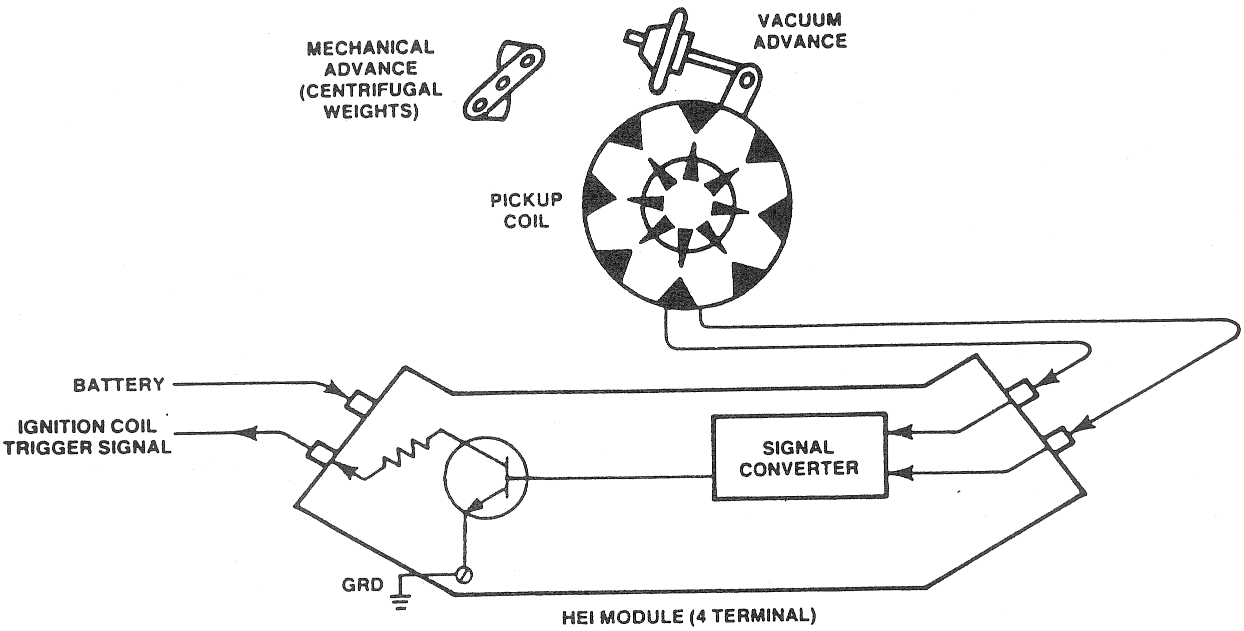


FIGURE 10-12
HEI schematic. (Courtesy of General Motors Corp.)

The period the points are closed is called *dwell* and is measured in the number of degrees of distributor shaft rotation. Most V-8 engines have a dwell of about 30 degrees before the points open to break the primary current flow. This dwell period remains unchanged regardless of engine speed. However, as engine speed increases, *the period of time the points are closed decreases.* This causes the secondary available voltage to decrease due to the reduction in magnetic field saturation time of the primary coil.

When the contact points close, the primary current does not instantaneously reach a value of 4.0 amperes due to self-induction of counter voltage in the windings. Thus, it takes several milliseconds for this value to be reached (Fig. 10-13).

At 1,000 engine rpm, the distributor shaft turns once every 0.12 second. During this time, the points are closed for 0.010 second (10 milliseconds) for every cylinder of the V-8 engine. As shown in the illustration, this is sufficient time for the primary current flow to build up to its maximum of just over 4.0 amperes.

However, as the engine speed goes up, the current flow time decreases. For instance, when engine speed increases to 2,000 rpm, the point-closed time for each saturation period is reduced to 5.0 milliseconds. This period only allows the primary current to build to 3.8 amperes. At 3,000 rpm, the saturation time drops to 3.3 milliseconds and the current flow to 3.2 amperes. As a result, the secondary available voltage begins to decay with reductions in time because there is insufficient current flow to cause complete magnetic saturation.

The HEI has two features that allow it to provide higher available voltage levels at high engine speeds. First, by lowering the resistance in the primary coil circuit, the time period necessary for the current to reach a maximum value is reduced (see Fig. 10-13). As shown in Fig. 10-13, it takes 10 milliseconds for the current to reach a maximum value in a coil that has a resistance of 2.6 ohms. But the HEI primary windings have a resistance of 0.5 ohm. This permits full current flow to be achieved in about 3.4 milliseconds.

Because it does take less time to reach maximum primary circuit current flow, magnetic saturation is obtainable at much higher engine speeds. But since the current flow is much higher in the HEI system, heat generation must be controlled to protect the module. This is done through the use of a dwell control circuit within the module.

The *dwell control circuit* electronically senses the primary current flow to see if it reached its maximum during the last dwell period. If maximum current flow did occur, the circuit provides no current reduction, and the dwell period remains the same.

If current flow becomes too high, such as at low engine speeds, the dwell period is shortened by turning on the primary current flow later. Since the turning off of the circuit is always at the same time, the dwell period has to be shorter.

If, on the other hand, maximum current does

not flow, as can occur at higher engine rpm, the primary circuit is turned on sooner. This results in a greater dwell period. Consequently, the HEI system is able to put out 35,000 volts to speeds above 3,000 rpm, while a conventional contact point system reaches its maximum available voltage at about 1,000 rpm and then begins to decay.

Finally, by using this dwell control to reduce the time current is flowing, system temperature is lower. This increases the reliability of the HEI system, in general, and the life of the module, in particular.

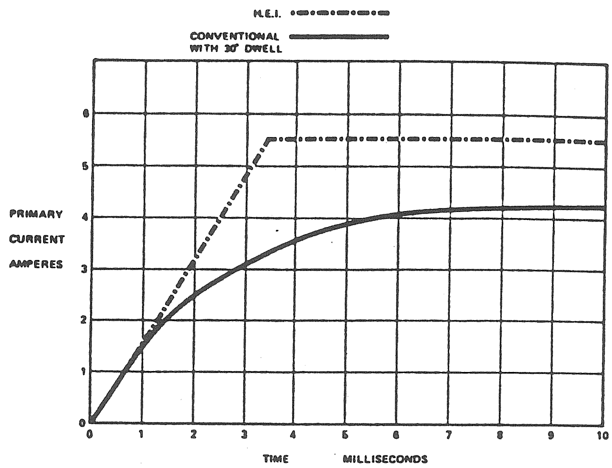


FIGURE 10–13
Primary current flow versus time. (Courtesy of General Motors Corp.)

Ignition Coil

The design and construction of the coil also affect the system's operation. The HEI coil has a low primary resistance and a size and shape so that it may be mounted in the distributor cap (Fig. 10–14). Resistance is decreased by reducing the length of wire used in the primary windings. By reducing the length of the wire used, low resistance is possible with a reasonable wire diameter.

In the oil-filled ignition coil used with the conventional system, the primary winding is wrapped around the secondary, which in turn is wound around the iron core (see Fig. 10–14). The HEI coil has the secondary winding wound around the primary and both are then wrapped over the iron core.

Moreover, the HEI coil is not oil-filled. Instead, its windings are covered with an epoxy compound for protection against moisture and arc over within the coil.

Another influence of less resistance in the HEI coil primary is the reduction of the inductance values of that coil. The *inductance (self-induction)* of a coil is its ability to induce a counter voltage while carrying an increasing or decreasing primary current. The counter voltage works against flow by trying to keep the current flow value in the wire from

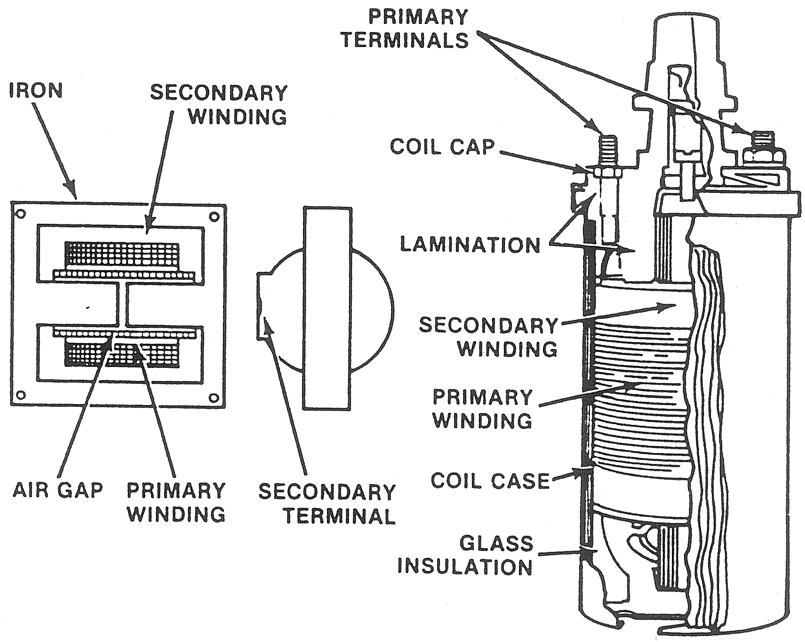


FIGURE 10–14
Conventional and HEI coil construction. (Courtesy of General Motors Corp.)

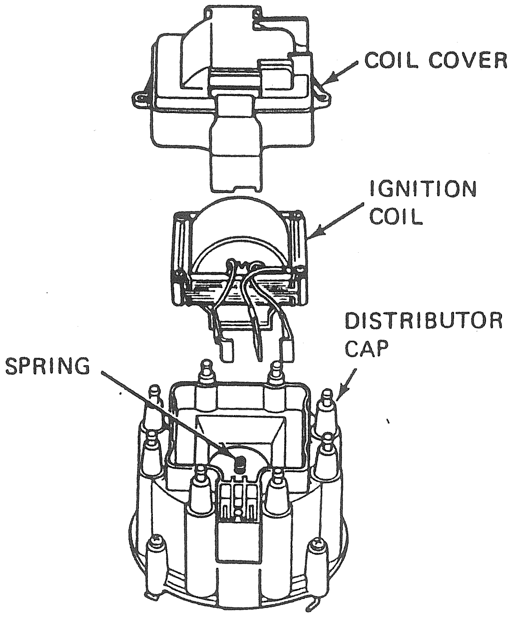


FIGURE 10-15
Distributor cap assembly. (Courtesy of General Motors Corp.)

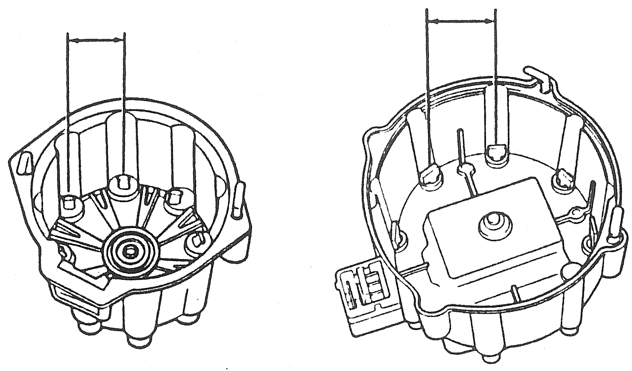


FIGURE 10-16
HEI plug electrode spacing. (Courtesy of General Motors Corp.)

changing. This slows up the saturation time and therefore limits the maximum secondary output of the coil.

Thus, by reducing primary inductance, secondary induced voltage is higher. This increases the spark duration over that found in a conventional system.

The HEI system was developed for use as an integrated unit that combines the distributor, magnetic pickup, ignition coil, and electronic module. This was done for two reasons. First, these parts are well protected from physical and environmental abuses. Second, the compact package reduces the number of electrical connections.

However, there are some HEI models that use a remotely mounted coil. This coil has the same construction as the integral type with the exception of a mounting bracket and a terminal for the high tension cable. This configuration is used on most in-line engines where additional distributor-to-hood clearance is necessary.

Distributor Cap

The distributor cap assembly of the integral model consists of the cap, coil, and coil cover (Fig. 10-15). The cap itself has the connection posts for the ignition and spark plug wires along with the connector plug from the lower housing assembly.

The coil rests on a seal in the cap. A spring, which passes through a hole in the seal, connects the high voltage coil secondary to the rotor contact in the cap. The cover protects the ignition coil from the effects of moisture and dust.

The HEI distributor cap is larger than the conventional unit (Fig. 10-16). This is due to the wide spacing that must exist between the electrode inserts to prevent high-voltage arc over between adjacent terminals and to ground via the distributor housing.

The higher voltage output of the HEI system requires that new insulation material be used for the cap and rotor to prevent carbon tracking and voltage arc over. The material used is a thermoplastic, injection-molded, glass-reinforced polyester that provides the dielectric and insulation properties needed.

The HEI distributor cap also uses new high voltage terminals. They are similar in appearance to spark plug terminals. These units provide easier attachment and better sealing for the plug wire connections. In addition, latches are used to ensure proper connection of the plug wires to the cap. The latches prevent any loosening or movement, which might reduce the moisture protection at the wire attaching point.

Spark Plug Wires

The spark plug wire used with HEI systems is *television radio suppression (TVRS)* wire with a carbon-impregnated cord conductor. The outer jacket is eight millimeters in diameter and is made of silicone rubber. This jacket material will withstand very high temperatures and is an excellent insulator for the higher voltages.

However, silicone is soft and very pliable; therefore, it is more susceptible to scuffing and cut-

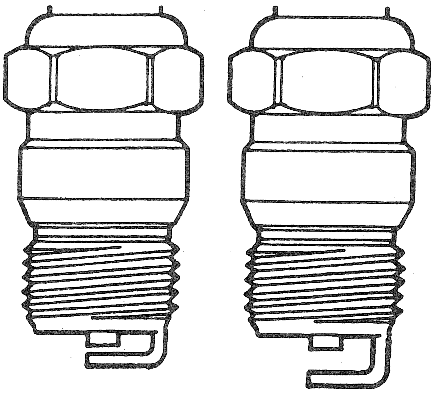


FIGURE 10-17
Conventional and wide gap spark plugs. (Courtesy of General Motors Corp.)

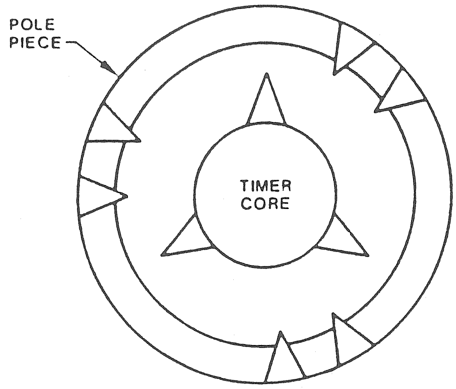


FIGURE 10-18
V-6 timer core and pole piece. (Courtesy of General Motors Corp.)

ting. For this reason, it is extremely important that the plug wires be handled with care. In addition, the cables must be routed so that they do not cross each other or are not in contact with other parts of the engine that might cause rubbing.

Spark Plugs

The HEI system is designed to use specially designed wide gap spark plugs (Fig. 10-17). These plugs have a longer side electrode. This design allows the proper configuration of the electrode at a 0.060-inch or 0.080-inch gap. Attempting to set a wide gap plug to 0.035 inch or a conventional plug to 0.060 inch could reduce spark plug efficiency and shorten its life.

HEI Models

There are two basic HEI distributor models used. The first has an ignition coil mounted within the distributor cap. This model is found on all V-8 and V-6 engines. The V-6 distributor differs in several ways from the V-8. For example, the V-6 distributor cap assembly has two less secondary wire terminals, and the six electrode inserts are unevenly spaced and have extended contacts on the inside of the assembly. These features are necessary to meet the requirements of the V-6's unique firing sequence, which is alternately at 45 degrees and 75 degrees.

Also necessary inside the distributor are a different timer core and pole piece (Fig. 10-18). The V-6 distributor has three evenly spaced teeth on the timer core and six alternately spaced teeth at 45 degrees and 75 degrees on the pole piece. (Remember the V-8 has a pole piece and timer core with the same number of teeth that are equally spaced.)

The second type of HEI distributor uses a remotely mounted coil that is similar in appearance to the one used with the integral coil (Fig. 10-19). Since the ignition coil is outside the distributor cap assembly, these units are slightly shorter than in the V-6 and V-8 models. Also, the external models require a few more wires to connect the coil to the distributor.

Inside these distributors, the number of teeth on the pole piece and timer core reflect the number of engine cylinders the unit is operating on. Therefore, a four-cylinder engine has four teeth on the pole piece and timer core, and a six-cylinder engine has six on each. In either case, the teeth are evenly spaced around the timer core and pole piece.

10-2 ELECTRONIC SPARK TIMING SYSTEM

Electronic spark timing (EST) systems have existed in different forms since 1977. EST is a microprocessor-controlled ignition system that electronically provides precise spark timing based on a number of engine operating conditions. The electronic spark timing, computer command control (CCC) version of the system is shown in Fig. 10-20. It consists of an HEI distributor and module, a number of sensors, and an EST electronic control module (ECM).

EST, HEI Distributor

The high energy ignition (HEI) distributor used with electronic spark timing (EST) resembles the integral unit described in the last section. However, the electronic spark timing HEI distributor does not

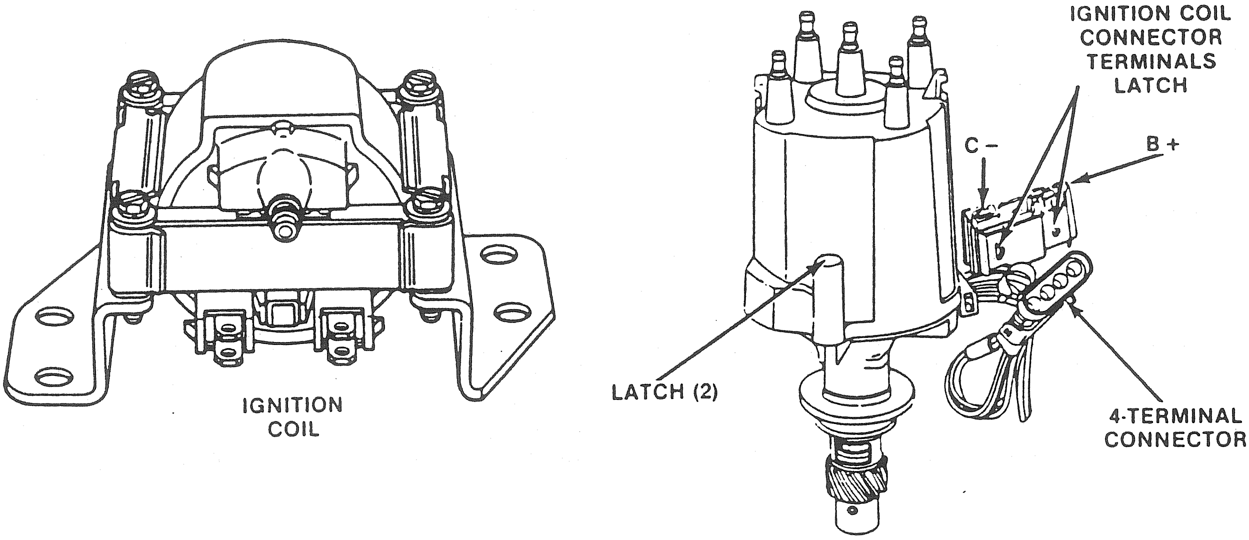


FIGURE 10-19
Remote coil and HEI distributor. (Courtesy of General Motors Corp.)

have vacuum or centrifugal advance mechanisms built in because the electronic control module now handles this function.

EST, HEI Electronic Ignition Module

The electronic spark timing HEI electronic ignition module performs the same function as its HEI counterpart discussed in the last section. The main difference between the two units is that the electronic spark timing HEI module has seven instead of four terminals.

Also notice in Fig. 10-20 what appears to be a relay with a double set of contact points in the HEI module. Actually, there is no electromechanical relay; instead, solid state circuitry is used for the switching function. The relay is only shown to make it easier to visualize how the EST system operates.

Coolant Temperature Sensor

The *coolant temperature sensor* sends an electrical signal to the electronic control module (ECM) relating to engine temperature (Fig. 10-21). Along with other functions, the coolant sensor signal will be used by the ECM to vary the amount of spark advance according to engine operating temperature.

The coolant temperature sensor is a thermis-

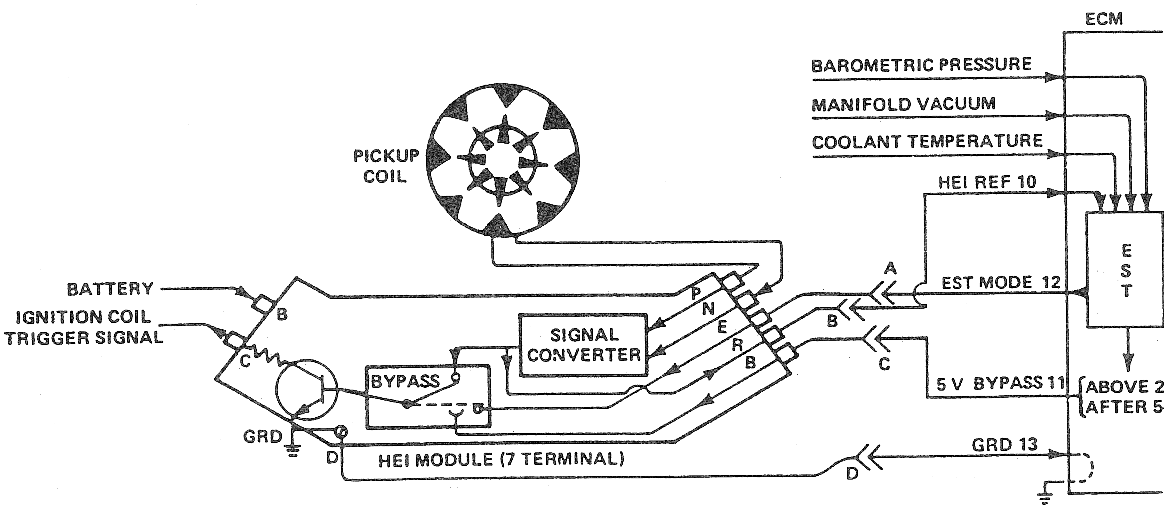


FIGURE 10-20
Electronic spark timing, computer command control schematic. (Courtesy of General Motors Corp.)

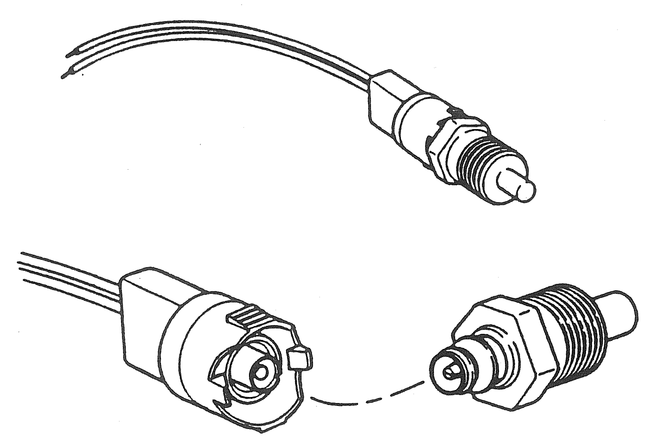


FIGURE 10-21
Coolant temperature sensor. (Courtesy of General Motors Corp.)

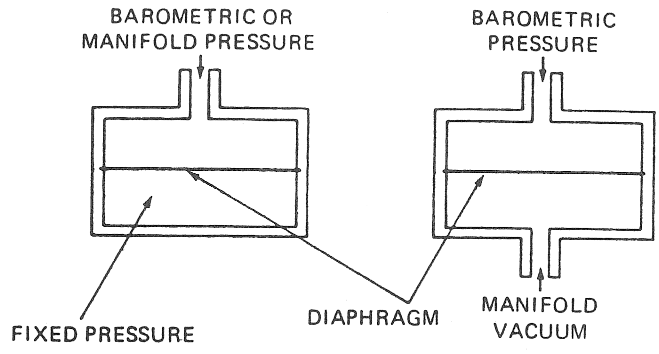


FIGURE 10-22
Pressure sensor design. (Courtesy of General Motors Corp.)

tor-type sensor that lowers its electrical resistance when coolant temperature increases. Likewise, the sensor's resistance raises as engine temperature decreases. As a result, the electrical output signal from the sensor varies with temperature.

Manifold Vacuum and Barometric Pressure Sensors

The barometric pressure and manifold vacuum sensors used in the electronic spark timing, computer command control system are the flexible resistor type (Fig. 10-22). That is, when the resistor is flexed, its resistance changes. As this occurs, the output signal varies from the sensor to the ECM. Pressure sensors are divided into two groups: absolute pressure and differential pressure sensors.

The *barometric (BARO) sensor* is the *absolute type*, which compares one pressure to a reference pressure or vacuum. The BARO compares both ambient and barometric pressures. The sensor then feeds a signal to the ECM based on ambient pressure changes due to altitude or weather. The signal voltage decreases with altitude but is not altered by the throttle opening.

Vacuum Sensor

The *vacuum sensor* is the *differential pressure type* in that the unit compares manifold pressure to atmospheric. The vacuum sensor is made like the absolute type with one exception. In the vacuum sensor, there is a pyrex tube located in the reference cavity that connects by a hose to the intake manifold. This design forms both vacuum and atmospheric reference cavities for differential sensor applications.

As manifold pressure is applied to one side of the diaphragm, the diaphragm deflects due to the effect of atmospheric pressures. This causes the diffused resistors to change their values proportional to the difference in pressure between the two cavities. With this design, the sensor's output voltage increases as manifold pressure decreases, which is an indication of increased vacuum.

The voltage output signal of the sensor is five volts at closed throttle. But as the engine operates under varying load conditions, the signal to the ECM changes with manifold pressure. In this way, the ECM can determine the best timing advance under given engine load conditions.

Electronic Control Module

The *electronic control module (ECM)* is a reliable solid state computer that contains the electronic spark timing (EST) circuitry. The ECM monitors and controls the functions of the computer command control system, including electronic spark timing. The ECM is located in one of several places in the passenger compartment.

EST Operation During Engine Cranking

During engine cranking, the HEI relay (solid state switch) is in the de-energized position (Fig. 10-23). The HEI relay connects the pickup coil to the base of the transistor. When the pickup coil applies a positive voltage to the transistor base, the unit turns on; with a zero voltage, the transistor turns off.

With the transistor turned on, current flows

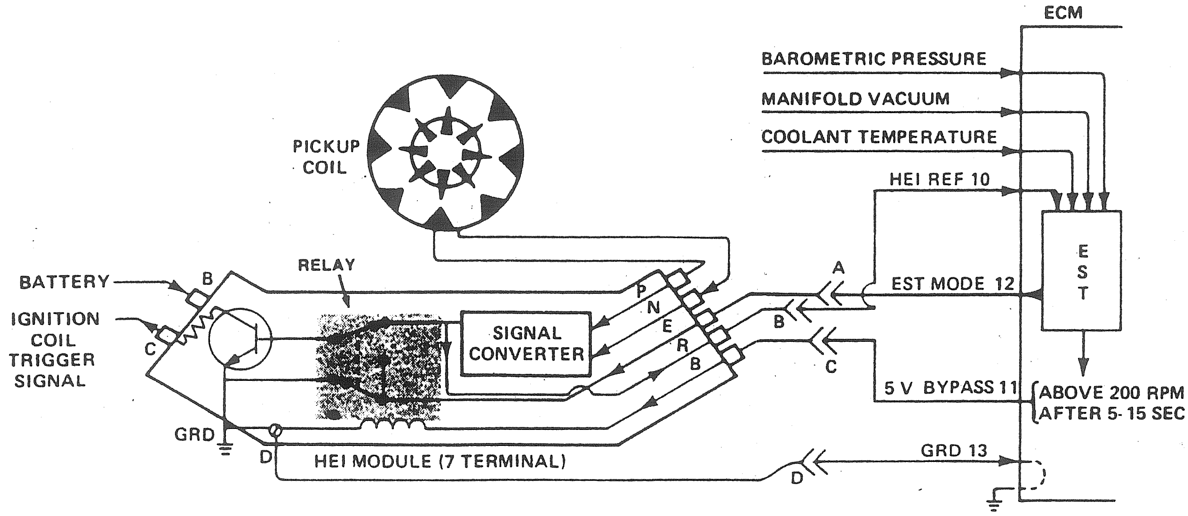


FIGURE 10-23
EST operation during engine cranking. (Courtesy of General Motors Corp.)

through the primary windings of the ignition coil. But when the transistor turns off, the primary current flow stops, and a spark occurs at the spark plug. This is called *module mode.* During this time, there is a small amount of timing advance that is built into the HEI module through a special circuit.

While the engine is cranking, the pickup coil delivers AC voltage to the signal converter in the HEI module. The converter changes the AC pickup coil signal to a DC square wave, so it can also be used by the ECM. This signal passes through HEI module Terminal R and on to the ECM as HEI reference voltage.

The ECM is capable of varying the time at which it directs an electronic spark timing (EST) signal back to the HEI module via its Terminal E. However, during the module mode, the second set of contacts grounds the EST signal.

EST Operation with the Engine Running

When the engine speed reaches a predetermined rpm (for our purposes, 200), the ECM considers it running. The ECM then applies a five-volt signal to the bypass Terminal B of the HEI module. The bypass voltage energizes the module relay (solid state switch). This action ungrounds the EST line and connects it to the base of the transistor, which also

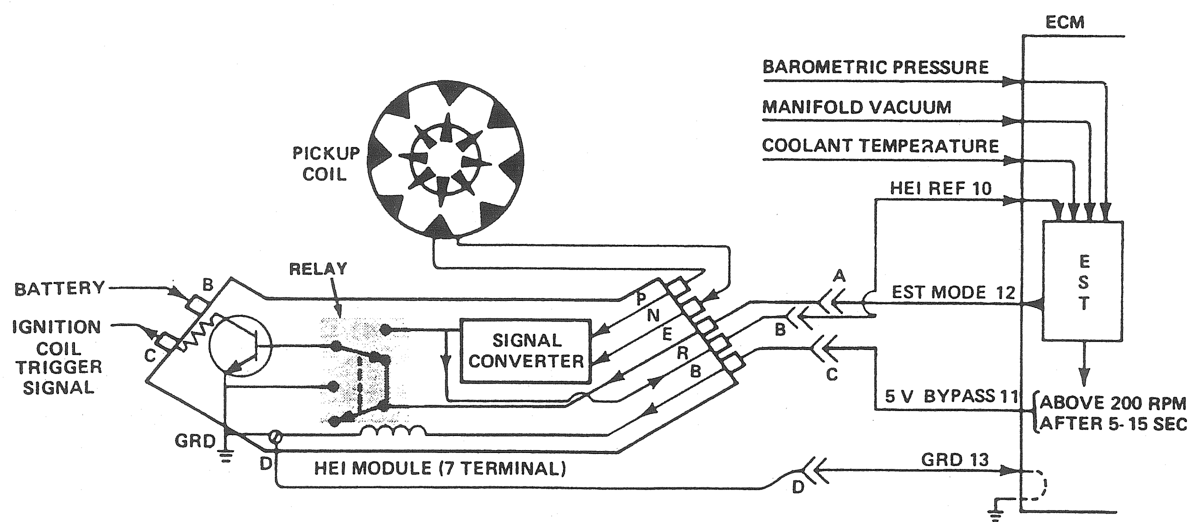


FIGURE 10-24
EST operation with the engine running. (Courtesy of General Motors Corp.)

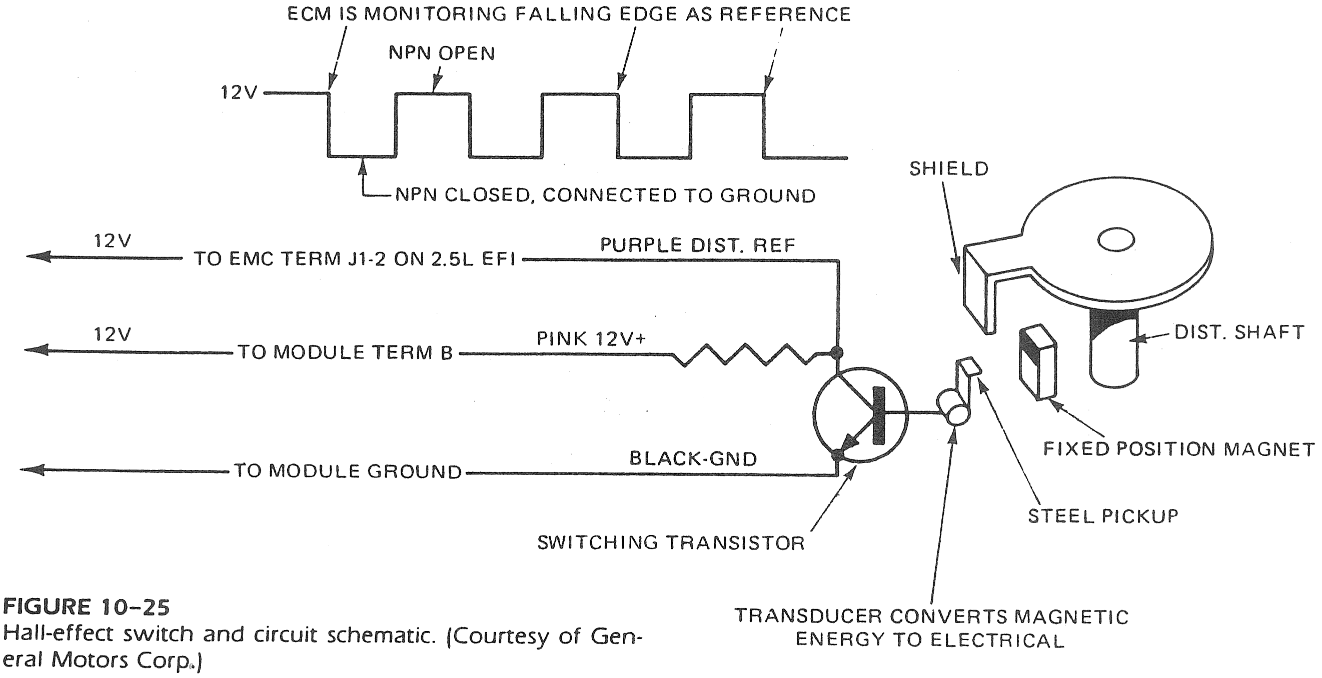


FIGURE 10-25
Hall-effect switch and circuit schematic. (Courtesy of General Motors Corp.)

bypasses the HEI module timing control (Fig. 10-24).

The operation of the HEI system is now under the control of the EST signal from the ECM. This is known as the *EST mode* of operation. The ECM can vary the time it directs the EST signal to the transistor and, by doing so, can tailor the timing to best suit the needs of the engines under all operating conditions.

Hall-effect Switch

The 1982 3.8-liter (229 cubic inch) odd firing engine and some 2.5-liter electronic fuel injected systems use a Hall-effect switch (Fig. 10-25). When used, the switch takes the place of the reference voltage from the HEI module Terminal R. The Hall-effect switch is added to the ignition primary circuit to permit the use of electronic spark timing (EST). It is necessary on the odd firing 3.8-liter V-6 due to the cylinder-to-cylinder difference in top dead center points. The switch itself informs the ECM which cylinder is to be fired next.

The Hall-effect switch mounts in the distributor above the normal pickup coil and HEI module (Fig. 10-26). The switch contains a small magnet that sits close to the Hall-effect electronic circuit. The HEI rotor attached to the distributor shaft has the same number of steel vanes, or shields, as there are engine cylinders. These vanes pass in a narrow space between the magnet and the electronic circuit or transducer. As the rotor turns, it alternately cuts off and then passes the magnetic field from the magnet to the electronic circuit. This induces the DC square wave signal into the transducer (as seen in Fig. 10-25).

HEI Pickup Coil Pulses

The HEI pickup coil's electrical pulses will switch off the primary ignition coil (1) to fire the spark plugs during engine cranking, (2) to fire the spark plugs with the engine operating at less than 400 rpm, (3) to fire the spark plugs when the diagnostic connector terminals A and B are connected for checking base timing, and (4) to fire the spark plugs when the five-volt bypass line is lower than three volts.

Hall-effect Switch Signals

The electrical signals from the Hall-effect switch will (1) cause fuel injection on engines so equipped under the above four conditions, (2) fire the spark plugs above 400 rpm, (3) provide more accurate timing signals, (4) send a reference pulse to the computer to indicate crankshaft degrees and speed, and (5) control fuel injection under all other operating conditions.

Hall-effect Distributor Operation

Figure 10-27 is a schematic of the EST system that uses the Hall-effect switch within the distributor.

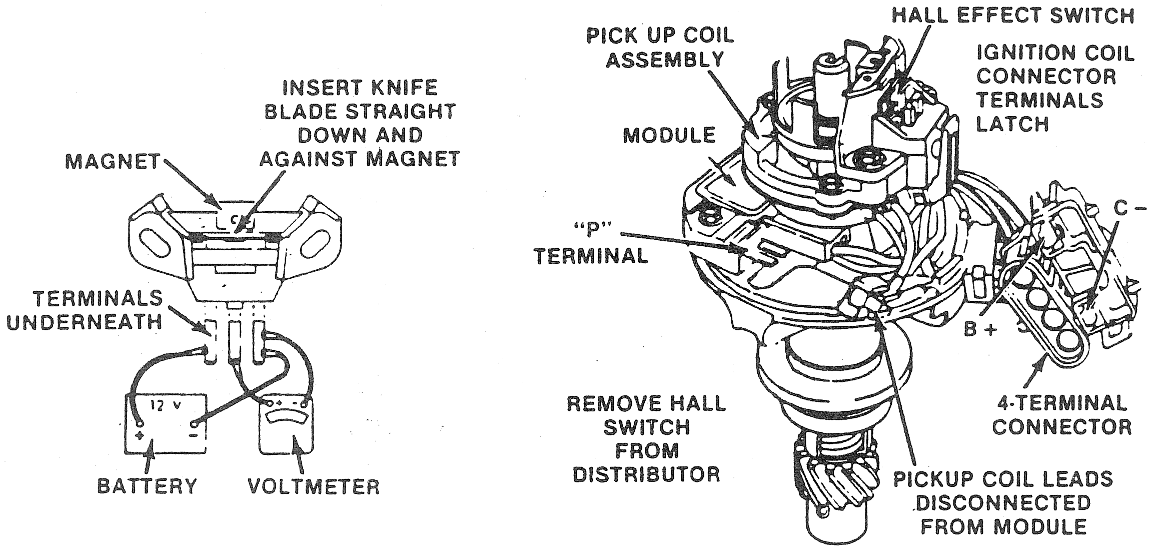


FIGURE 10-26
Hall-effect switch installation in the distributor. (Courtesy of General Motors Corp.)

The operation of this system is the same as for the one described earlier except for the action of the Hall-effect switch and its circuit. In this system, the HEI module supplies 12 volts through a resistor to the collector of the Hall-effect circuit transistor. The reference line to the ECM also connects to the collector. The emitter of the transistor connects to ground.

The base of the collector is controlled by the Hall-effect switch. When magnetism is allowed to reach the transducer of the switch, its induced voltage turns the transistor on. With it on, the reference voltage to the ECM is under one volt, which is the normal drop across the transistor.

When the magnetic field to the Hall-effect transducer is cut off by a vane, the transistor turns off. At this point ECM reference voltage becomes 12 volts. With the ignition key on, a voltage is present at the transducer output that will be dependent on the position of the vane of the distributor rotor. However, with the engine running, the output reference voltage will be about one-half that of the battery or six volts.

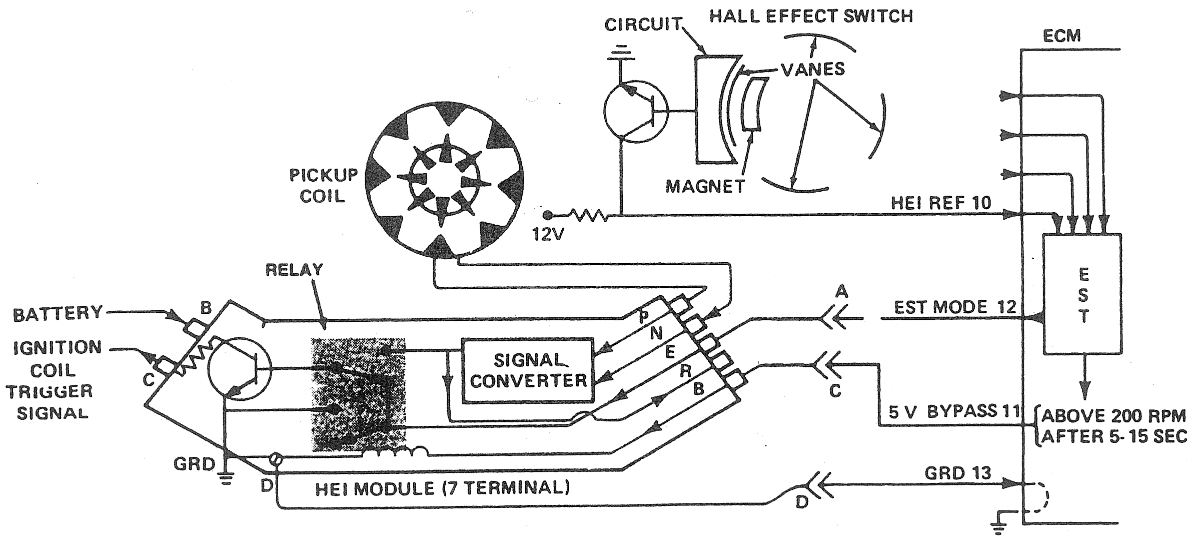


FIGURE 10-27
Hall-effect distributor and EST system operation. (Courtesy of General Motors Corp.)

10-3 ELECTRONIC SPARK CONTROL SYSTEM

The *electronic spark control (ESC) system* is used along with electronic spark timing (EST) on turbocharged engines. A *turbocharged engine* uses its exhaust gas flow to drive a small turbine. The turbine is a rotary air pump that, in turn, supplies air to the carburetor. The air is forced into the carburetor at a pressure above atmospheric, which results in more air/fuel mixture being admitted into the cylinders. This action raises the engine's volumetric efficiency and therefore its power.

However, since air is forced into the carburetor under a pressure higher than atmospheric, overall cylinder pressures are higher. This higher pressure can cause detonation in the turbocharged engine.

The ESC system is designed to prevent excessive detonation; a small amount of knock is normal on engines equipped with this system. To control detonation, the system incorporates a sensor and an electronic spark control ECM (controller) (Fig. 10-28). However, the electronic spark timing HEI module within the distributor remains unchanged.

Detonation Sensor

The *detonation sensor* mounts on the intake manifold. The sensor detects the vibrations caused by detonation. When detonation occurs, the sensor sends a signal to the ESC controller.

ESC Controller Action

The *ESC controller* evaluates the sensor signal and then directs an electronic spark timing ESC signal to the distributor to retard the timing. In case of detonation, the electronic spark timing ESC signal would be retarded by the controller about four degrees each second until the detonation sensor stopped detecting engine vibrations. After the detonation has stopped, the timing signal is returned to normal at a slower rate than it was retarded.

10-4 DISTRIBUTORLESS IGNITION SYSTEM

The *distributorless ignition system (DIS),* as its name implies is designed to do away with the me-

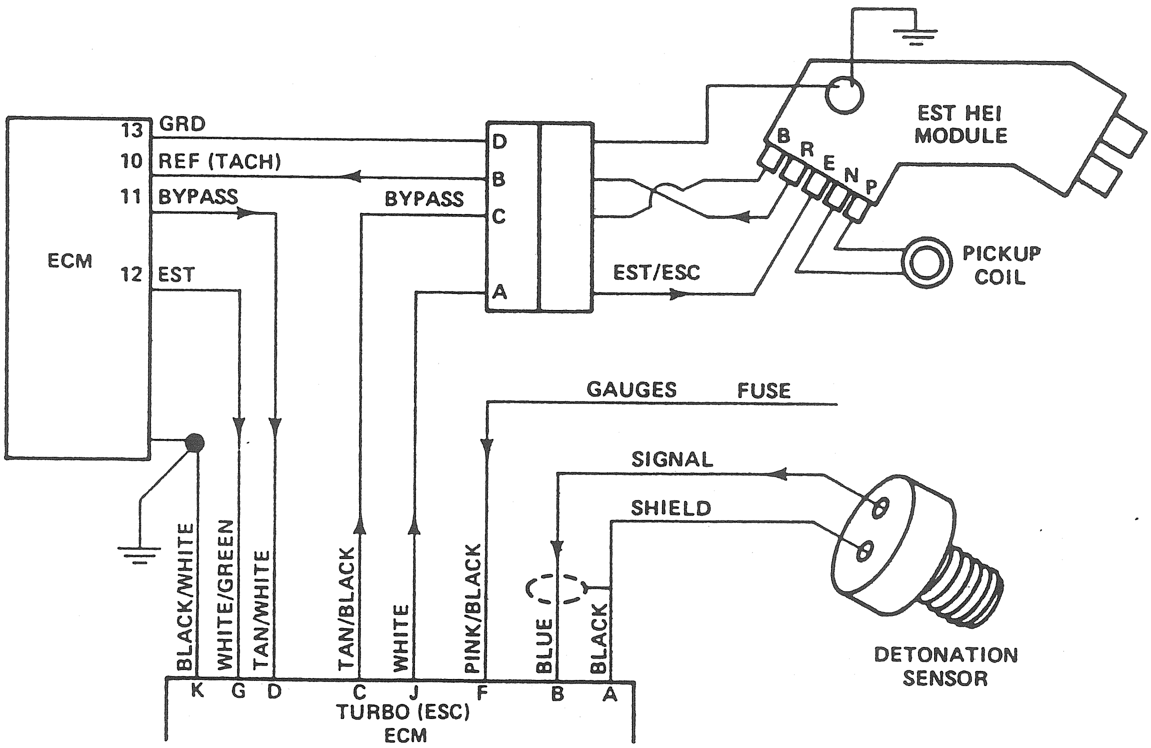


FIGURE 10-28
Electronic spark timing, electronic spark control schematic. (Courtesy of General Motors Corp.)

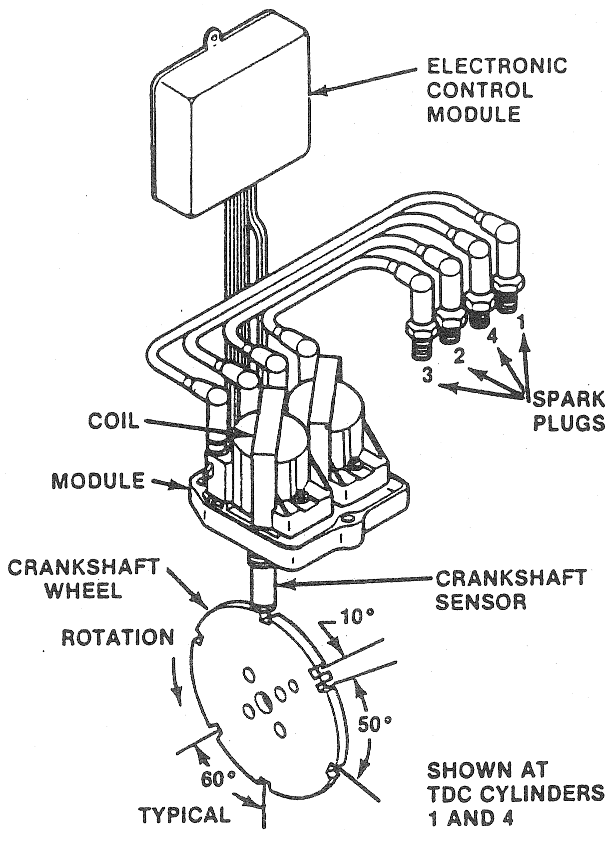


FIGURE 10–29
Typical distributorless ignition system components. (Courtesy of General Motors Corp.)

chanical distributor system (HEI) for controlling secondary ignition voltage. So far, this system is used on 2.0-, 2.5-, 2.8-, 3.0-, and 3.8-liter General Motors engines.

System Names

Different names are given the DIS system relative to the actual car division that uses it. The names in current use include

- distributorless ignition system (DIS),
- computer controlled coil ignition (C3),
- direct ignition system (DIS), and
- integrated direct ignition (IDI).

Advantages of the DIS System

The DIS offers a number of advantages over HEI. Distributorless ignition systems eliminate the possibility of tampering or misadjustment. They use even

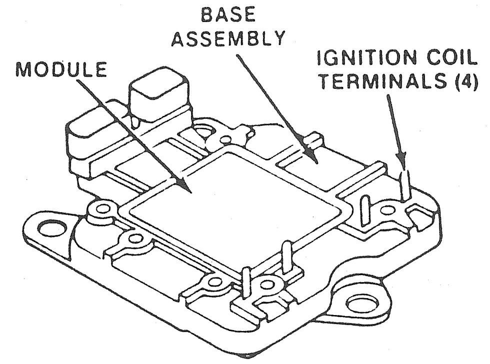


FIGURE 10–30
The base assembly forms the framework of the system. (Courtesy of General Motors Corp.)

more sophisticated electronics. Mechanical timing adjustments are eliminated. There are fewer moving components. Distributorless ignition systems also can be remotely and more compactly mounted.

System Components

In order to function, all systems have three components in common. There are the ignition module, coils, and a crankshaft sensor (see Fig. 10–29). However, the 3.8-liter engine also requires a camshaft sensor and interrupter.

Base Assembly and Ignition Module

The ignition module of the DIS is housed in the *base assembly*, which provides the basic support framework for the entire system (Fig. 10–30). The base not only securely supports the module and coils but also provides the means of mounting the DIS system to the engine.

The *ignition module* has two basic functions. First, it controls the current flow in the primary winding circuit of the coils by means of transistors. Second, the DIS module controls spark timing under 400 engine rpm.

Ignition Coils

The *ignition coils* mount above the module and base assembly (Fig. 10–31). The DIS coils are the inductive type and operate in much the same manner as those used in the HEI design.

DIS uses one coil for every two cylinders. Each coil has two secondary towers to simultaneously supply high voltage to two spark plugs. The coil cylinder pairings by engine type are

• four-cylinder—first and fourth, and second and third;

• six-cylinder—first and fourth, second and fifth, and third and sixth.

The V-6 Buick engine DIS can use either a Type I or II coil application (Fig. 10-32). This is due to the different design of the module and coil pack assemblies. *Verification of the coil application is important because diagnostic procedures are different for each.*

The type I application is used only with the 3.0-liter and 3.8-liter engines. Type I can be identified by the three coil terminals located on each side of the coil. Also, this arrangement offers the three-in-one coil pack design. The Type II application has all six coil terminals on one side. Moreover, each coil pack assembly is separate.

Magnetic Crankshaft Sensor

There are two styles of crankshaft sensors used: the magnetic type and the Hall-effect. The type used in the DIS is determined by engine application.

The *crankshaft sensor* shown in Fig. 10-33 is a magnetic switch. It is used to provide the ignition module and the ECM with engine rpm and crankshaft information in much the same manner as the HEI pickup coil.

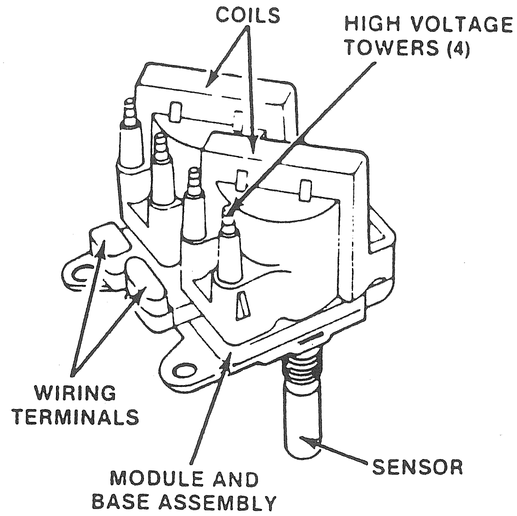


FIGURE 10-31
Ignition coil installation. (Courtesy of General Motors Corp.)

This sensor is made up of a permanent magnet with a coil of wire wrapped around it. The sensor is positioned 0.050 inch, plus or minus 0.020 inch, from the slotted portion of the crankshaft, known as the reluctor. On the 2.0-, 2.5-, and 2.8-liter engines, the reluctor has seven slots, six of which are equally spaced 60 degress apart. The seventh is set ten degress *after top dead center (ATDC)* from the sixth slot position. However, this is not the sixth piston position. The seventh slot is used to generate a sync pulse (see Fig. 10-29).

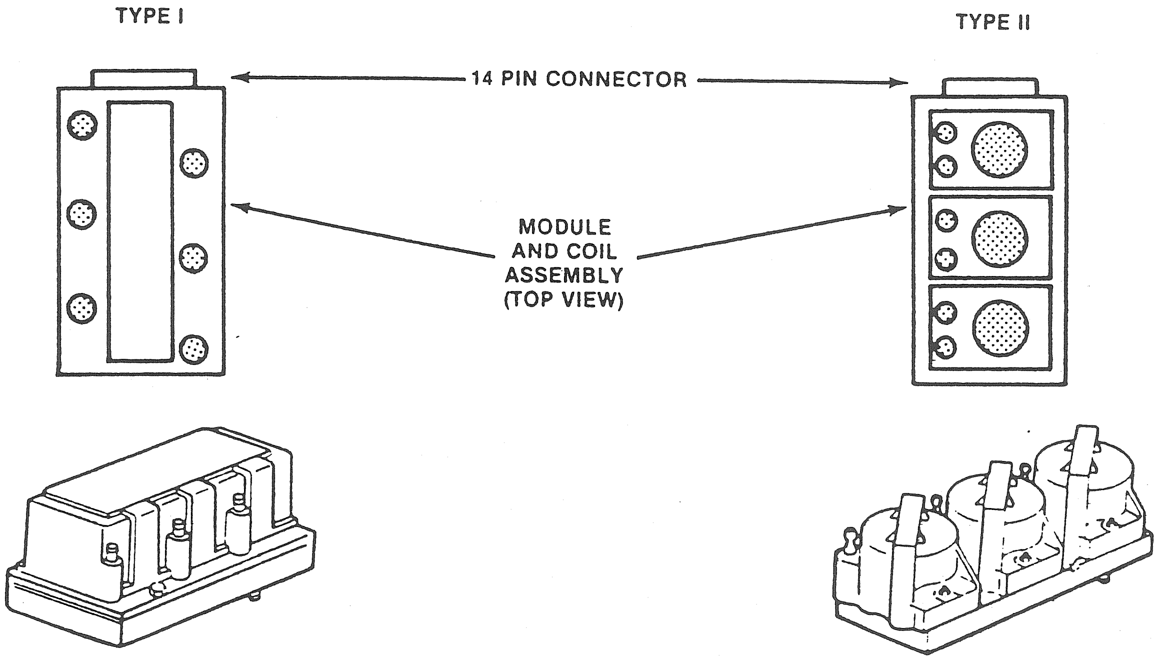


FIGURE 10-32
Type I and II coil identification. (Courtesy of General Motors Corp.)

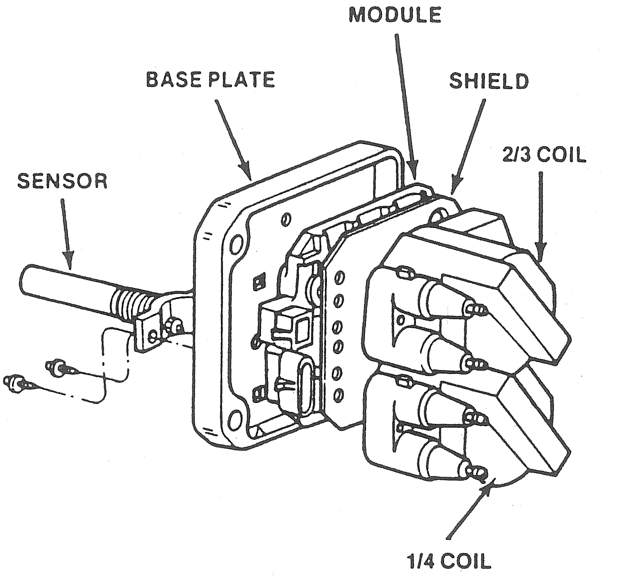


FIGURE 10-33
Sensor, base plate, module, and coils for a 2.5-liter engine. (Courtesy of General Motors Corp.)

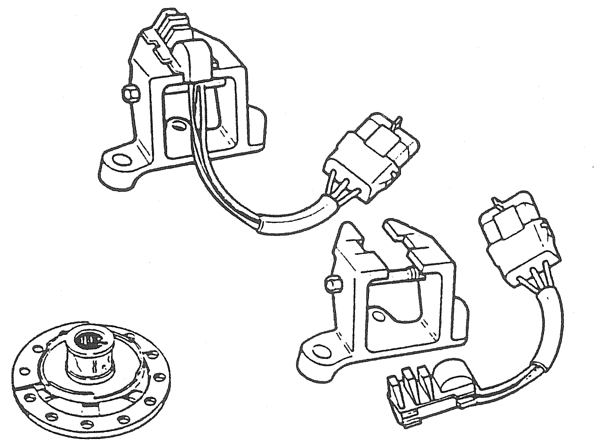


FIGURE 10-34
Hall-effect crankshaft sensor. (Courtesy of General Motors Corp.)

As the reluctor rotates as part of the crankshaft, the slots change the magnetic field of the sensor as they pass by its tip. The magnetic field therefore increases and then quickly decreases each time a slot passes the sensor. This creates an induced voltage pulse in the coil of wire in the sensor.

The voltage amplitude varies directly with engine speed. For instance, the range is from about +0.5 volt to −0.5 volt on every slow cranking speeds. At higher speeds, the range is from approximately +1.5 volts to −1.2 volts.

The gap between the sensor tip and the crankshaft reluctor has an effect on sensor output. For example, an air gap smaller than 0.030 inch creates larger than normal voltages. A gap larger than 0.070 inch causes smaller than normal voltages.

The smaller gap can result in high speed problems due to the voltage output exceeding the module's input handling ability. The larger gap, on the other hand, could cause starting problems because the sensor output is not enough to trigger the ignition module. The induced voltages must rise above a certain positive value and then move toward positive zero volts on a negative transition. The module triggers off the primary coil current flow at the positive zero crossing of the AC waveform.

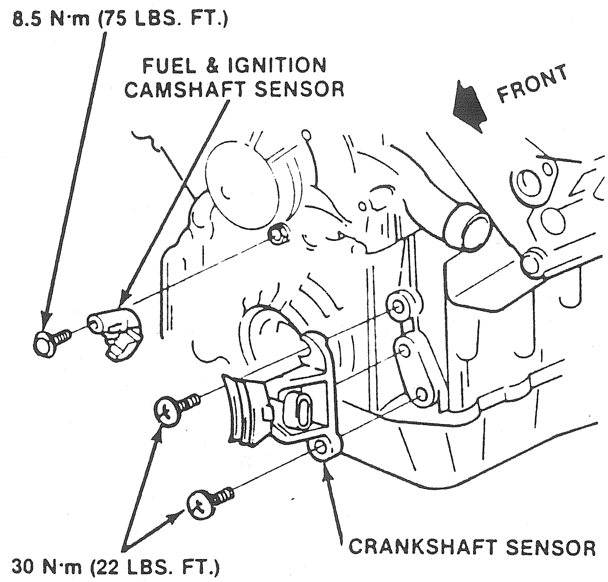


FIGURE 10-35
V-6 cam and crankshaft sensors for a 3.8-liter engine. (Courtesy of General Motors Corp.)

Hall-effect Crankshaft Sensor

The 3.8-liter V-6 engine uses a Hall-effect crankshaft sensor (Fig. 10-34). This sensor provides only the crankshaft rpm signal to the ignition module. The sensor mounts on the front of the engine timing cover just behind the harmonic balancer.

A magnet and *interrupter ring* attach to the backside of the balancer. The interrupter has three window slots positioned 120 degrees apart. The sensor mounts in a pedestal-type holder. When properly adjusted, the sensor has an equal distance of 0.025 inch clearance on side of the interrupter ring.

The 3.0-liter engine uses a combination crankshaft sensor that is similar in appearance and location to the 3.8-liter application. However, the 3.0-liter sensor provides information on both the crank-

shaft rpm and the first cylinder's *top dead center (TDC)* position. To do this, the balancer has a second interrupter ring that has only one window slot.

Camshaft Position Sensor

Along with an external, remotely mounted crankshaft sensor, the 3.8-liter, V-6 engine has a Hall-effect camshaft sensor (Fig. 10-35). This sensor is timed to the camshaft in much the same way as the HEI distributor.

The *camshaft sensor* provides the ECM with information on the first cylinder's TDC position. This signal is used to synchronize the firing of the ignition coil in relation to the crankshaft, pistons, and intake and exhaust valves. This synchronization enables the ignition module and the ECM to control the amount of spark advance and to time the opening of the sequential fuel injectors.

The camshaft sensor is located on the timing cover behind the water pump, near the camshaft sprocket (see Figs. 10-35 and 10-36). The sprocket has a magnet mounted on it that activates the Hall-effect switch in the sensor.

As the camshaft sprocket turns, its magnet creates a signal in the Hall-effect switch that activates the sensor circuit transistor (Fig. 10-37). When this occurs, the transistor grounds the signal line to the DIS module, pulling the crank sensor's applied line voltage down to a low value. This is interpreted as the *cam signal (synchronization pulse)*.

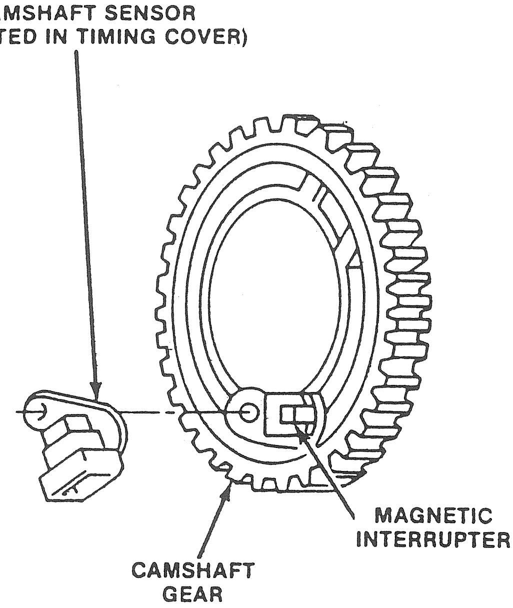


FIGURE 10-36
Design of the camshaft sensor. (Courtesy of General Motors Corp.)

Due to the manner in which the crank sensor operates, its signal is always a series of either high or low DC voltage square wave signals. However, as the camshaft sprocket rotates, its magnet turns off the transistor once, resulting in one signal each revolution of the sprocket.

The cam signal is created as the first and fourth pistons reach about 25 degrees after top dead

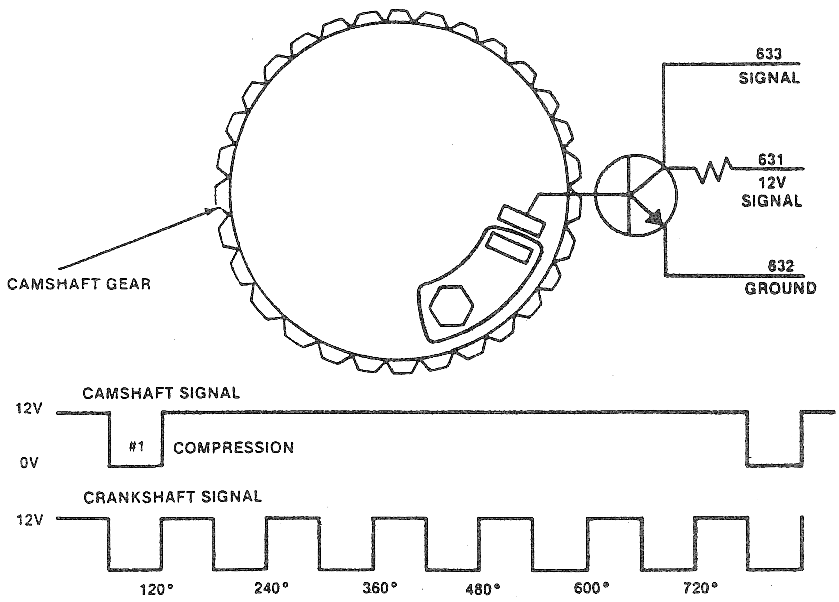


FIGURE 10-37
Camshaft circuit operation. (Courtesy of General Motors Corp.)

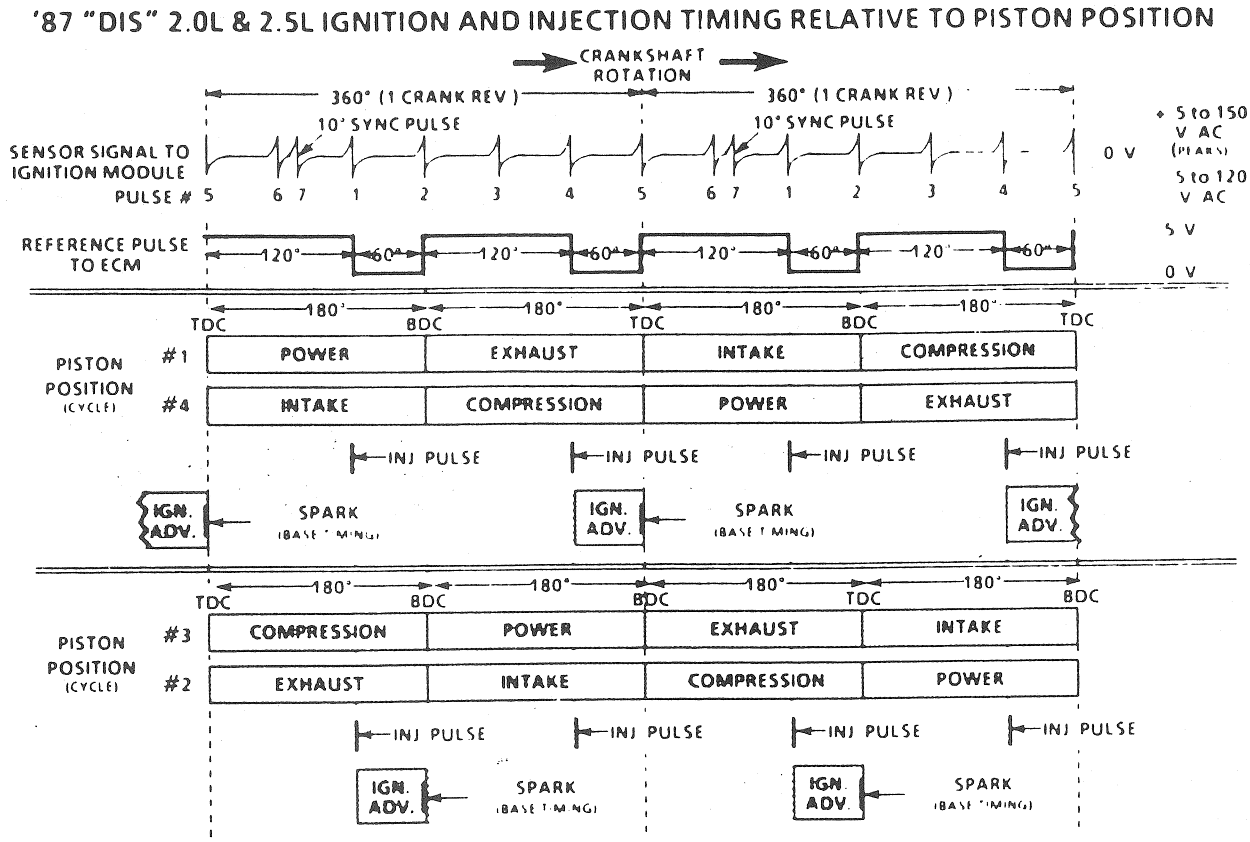


FIGURE 10-38
Ignition and injector timing in 2.0- and 2.5-liter engines. (Courtesy of General Motors Corp.)

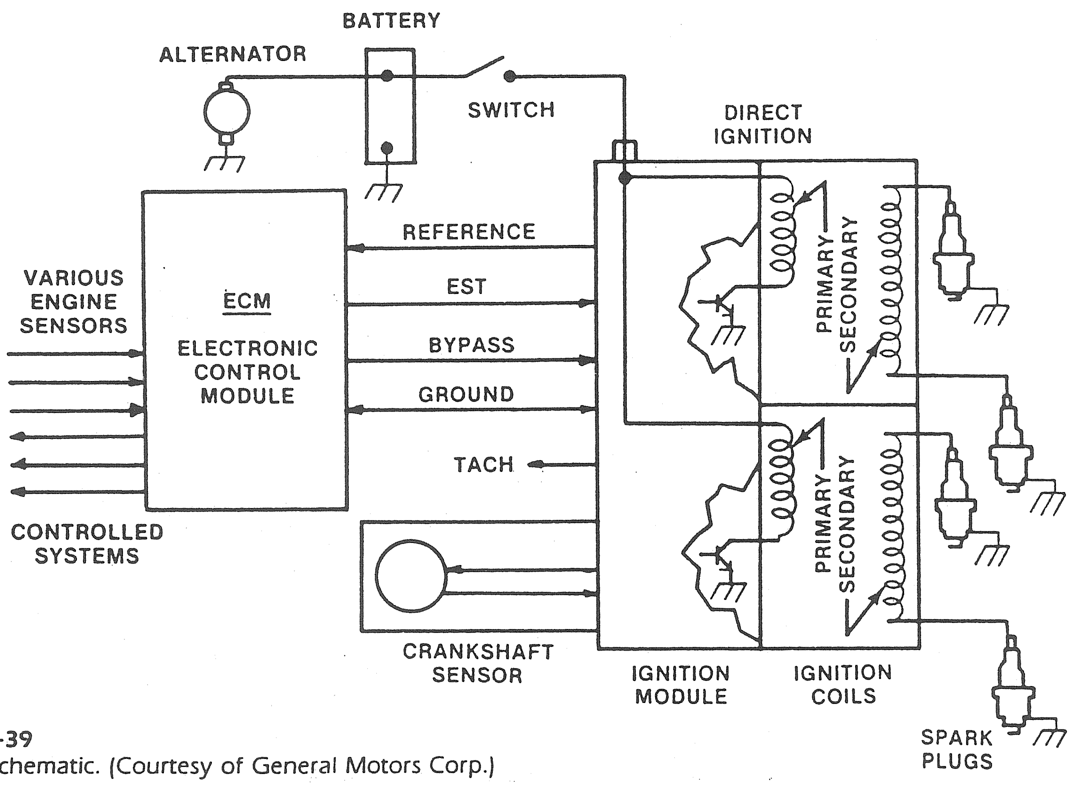


FIGURE 10-39
DIS wiring schematic. (Courtesy of General Motors Corp.)

center (ATDC). It is then used by the DIS module to begin the ignition coil firing sequence starting with the Number 3-6 coil. The firing sequence begins with this coil because the sixth piston is now at the correct position in the compression stroke for its spark plug to be fired. The plug for the third cylinder also fires but its piston is on the exhaust stroke.

DIS System Operation

DIS uses a *waste spark* method of spark distribution. Each cylinder is paired with another, such as the first and fourth and the second and third. The spark occurs in the cylinder with its piston coming up on the compression stroke, and in the paired one with its piston moving up on the exhaust stroke (Fig. 10-38).

The cylinder piston that is on the exhaust stroke requires very little of the available coil energy to fire its spark plug. Therefore, all the remaining energy is used as necessary by the cylinder on the compression stroke. The same process is repeated when the cylinders reverse roles.

The center electrodes of two spark plugs are connected to the ends of each coil's secondary winding (Fig. 10-39). An ignition module transistor controls the current flow through each coil primary winding.

The transistors control the 8.5 amperes to 10 amperes of primary current flow by being switched on and off. A positive voltage at the base of the transistor turns the collector-emitter circuit on and allows primary current to flow. The direction of the current flow is from the ignition switch, through the module and primary winding, to the collector-emitter of the transistor, and to ground.

The current flow in the primary windings creates a magnetic line field. As current flow stops, the magnetic field collapses and induces a voltage in the secondary winding. This action produces the necessary high voltage to fire both plugs in series.

The time lag between both plug firings is about one to two milliseconds. The plug for the cylinder at the end of its exhaust stroke fires first because the atmospheric pressure between its electrodes only requires 2,000 volts to 3,000 volts to form the arc. This leaves ample available voltage to fire the other plug in the cylinder at the end of its compression stroke.

When the engine is operating at normal speeds, the bypass signal from the ECM to the module will effectively connect the base of the transistor to the EST terminal. The EST signal is determined not only by the reference signal to the ECM but also as a result of signals coming from the other engine sensors, which are at the same time directing voltage pulses to the ECM. Under these conditions, the ECM, via the EST signal, is controlling the ignition timing and is constantly tuning the engine for control of exhaust emissions and good fuel economy and performance.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. What determines the name given to a particular distributorless ignition system (DIS) [10-4]?

2. What are the benefits provided by a high energy ignition (HEI) system [10-1]?

3. Electronic spark control (ESC) is found on what type of engine configuration [10-3]?

4. In HEI ignition, what are the purposes of the current and dwell control systems [10-1]?

5. What design changes did electronic spark timing (EST) make to the basic HEI system [10-2]?

REVIEW

1. Each end of a DIS ignition secondary coil connects to a [10-4]
   a. primary winding terminal.
   b. transistor terminal.
   c. spark plug wire.
   d. none of these.

2. Where is the ignition coil located on the HEI

system [10-1]?
a. inside the distributor
b. outside the distributor
c. both a and b
d. neither a nor b

3. Which system uses waste spark distribution [10-4]?
a. HEI, EST
b. HEI, ESC
c. HEI
d. none of these

4. When does the HEI pickup coil produce a positive zero voltage [10-1]?
a. as the pole piece and timer core teeth align
b. as the pole piece and timer core teeth move apart
c. as power is sent to the module
d. as power is cut off to the module

5. Which DIS-equipped engine uses a Hall-effect cam and crankshaft sensor [10-4]?
a. 3.8-liter
b. 2.0-liter
c. 2.5-liter
d. 3.0-liter

6. The vacuum advance moves what component with the HEI distributor [10-1]?
a. timer core
b. pickup coil assembly
c. ignition coil
d. rotor

7. In a DIS system, what component controls engine timing under 400 engine rpm [10-4]?
a. ECM
b. ignition module
c. pickup coil
d. Hall-effect switch

8. The HEI switching transistor's base circuit receives what type of signal [10-1]?
a. AC signal
b. DC signal
c. either a or b
d. neither a nor b

9 Which system has no mechanical timing adjustments [10-4]?
a. DIS
b. HEI
c. HEI, EST
d. both a and b

10. Which system's ignition module has a solid state switch connected to the transistor base circuit [10-2]?
a. HEI, EST
b. DIS
c. DIS, EST
d. ECM

11. If detonation occurs in an engine with ESC, how is its timing affected [10-3]?
a. It retards four degrees for every second of detonation.
b. It begins to return to normal as the detonation stops.
c. both a and b
d. neither a nor b

12. The EST computer command control system requires how many engine sensors [10-2]?
a. one
b. two
c. three
d. four

13. The detonation sensor is located where [10-3]?
a. cylinder head
b. intake manifold
c. water jacket
d. ECM

14. In the EST system, what controls the operation of the switching transistor during engine cranking [10-2]?
a. EST signal
b. bypass signal
c. coolant sensor signal
d. pickup coil signal

Chapter 11

TESTING TYPICAL GENERAL MOTORS ELECTRONIC IGNITION SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- explain the general precautions relating to testing General Motors electronic ignition systems.
- demonstrate the use of test equipment used on General Motors electronic ignition systems.
- describe how to test the high energy ignition (HEI) system.
- explain how to check the HEI electronic spark transfer system.
- describe the test procedures for the HEI electronic spark control system.
- explain how to check the distributorless ignition system (DIS) for a no-start condition.

Since its introduction in 1974 the basic high energy ignition (HEI) system has undergone a number of design changes, most of which have dealt with the introduction of various forms of electronic spark control systems. These spark control systems vary for different model years and vehicle configurations. Moreover, in recent years, General Motors started using the distributorless ignition system (DIS) along with electronic spark control.

Due to the variations in these systems, it would be impossible to discuss the service techniques on them all within the space available in this chapter. For this reason, this chapter provides samplings of procedures used on the various systems to provide you with an introduction to the process. *Always follow the manufacturer's instructions guides, and specifications when testing any system application in order to prevent damage to its many components.*

In the upcoming sections, you will find step-by-step electrical test procedures on system components. These steps are needed to locate the cause of either a no-start condition or poor performance.

11-1 GENERAL PRECAUTIONS AND TEST EQUIPMENT

Before learning to test General Motors ignition systems, you must review the general precautions for working on electronic ignition systems, in general, which are listed in the box below. In the box below are general precautions for working on General Motors systems. Also, always observe the safety instructions outlined in Chapter 5.

General Precautions

The precautions and instructions listed below and on pages 200–201 will not only save you time in locating the actual cause of a problem but prevent the possible destruction or replacement of an otherwise serviceable part.

General Motors Systems

1. Disconnect the distributor harness connectors before conducting a compression test.

2. Do not operationally test the secondary voltage of the HEI system by removing a plug wire. This can destroy the ignition module.

3. Never ground the tachometer terminal on the HEI distributor cap or coil.

4. To remove spark plug cables, twist the boot one-half turn and pull on it. *Do not pull on the wire itself.* A light coat of silicone grease inside the spark plug wire boot will seal the connection and aid with future removal.

5. Apply the special heat-dispersing compound to the base of the ignition module during its replacement. Without this compound, the heat build-up will cause module failure. The various manufacturers of this compound and the part numbers are NAPA Echlin TPL45, Delco D1920, Dow Corning Compound 5, GM 1974984, General Electric G642, and Dow Corning 341.

6. For integral HEI coils, lubricate the rubber washer seal between the coil and distributor cap with silicone grease. If this is not done, moisture and dust may contaminate the distributor cap causing misfiring and burn through.

7. A burned through rotor is usually the result of high secondary resistance. In this case, check all spark plug wires and connections. Also, inspect the carbon brush inside the distributor cap for correct installation and excessive resistance.

8. If the complaint is excessive engine detonation, check the coolant level of the vehicle, and fill as necessary.

9. If the engine detonates or has poor performance, make sure the ignition timing is set to the specifications on the emission label. Reconnect the vacuum advance on early HEI systems after completing the check.

10. On electronic spark control (ESC) systems, inspect the detonation sensor for its physical condition and proper installation. Make certain the detonation sensor wire is not routed next to the distributor or any spark plug wires.

11. Check catalog applications for ignition coil and pickup coil combinations on given electronic spark transfer (EST) and ESC configurations. For instance, ignition coils with red and yellow leads must be matched to pickup coils with yellow connectors. Ignition coils with red and white wires must be mated to a pickup coil with a clear, black, or blue connector.

12. Always check on ohmmeter's calibration before using it to test circuit resistance or continuity.

13. Beginning with the 1980 computer command control (C3) system, *use a high input impedance digital volt-ohmmeter (DVOM) to check component or circuit resistance or voltage.*

Test Equipment

Before you begin the ignition test procedures that follow, be sure you have an accurate analog volt-ohmmeter (*a high impedance DVOM for C-3 and later systems*), a power timing light with induction pickup, a spark tester, jumper leads, a tachometer, a vacuum pump, and a test light.

Larger pieces of equipment that are necessary include an oscilloscope and module tester. The scope will be used to check the operation of the pickup coil and secondary ignition circuits. A unit that is especially helpful is the Allen "Smart" scope because it is capable of reading pickup coil signals. The module tester electronically checks the serviceability of the distributor ignition module.

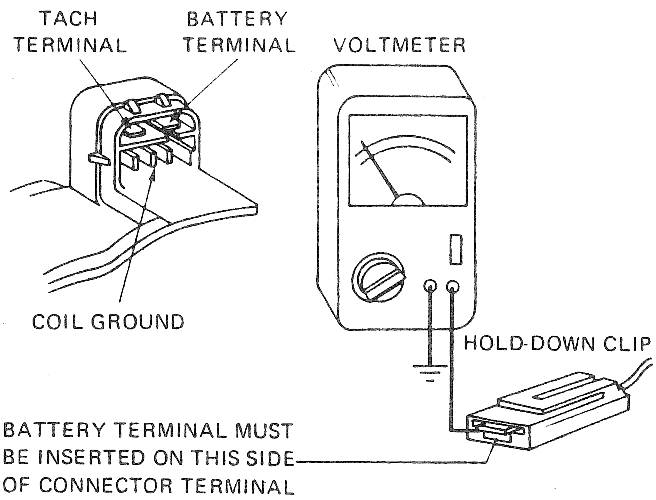


FIGURE 11-1
Testing the coil's run voltage.

11-2 TESTING A TYPICAL HEI SYSTEM

If an engine equipped with an integral HEI system will not start, remove a plug cable and connect it to a well-grounded spark tester. Turn the engine over with the ignition switch, and check for a spark at the tester. If there is no spark, troubleshoot the ignition system to locate the cause of the problem by following these steps.

Step 1—Coil Voltage Test in the Run Position

To determine if the coil is receiving sufficient voltage with the ignition switch in the RUN position, do the following:

1. With the ignition switch off, disconnect the battery wire from the distributor cap terminal (Fig. 11-1).

2. With the leads of the voltmeter, measure and record the voltage of the battery.

3. Attach the negative (−) lead of the voltmeter to a good ground.

4. Connect the positive (+) voltmeter lead to the connector of the distributor battery lead.

5. Turn the ignition switch to the RUN position and note the reading on the voltmeter.

6. The reading at the connector should be within one volt of that of the battery. If the reading is satisfactory, go to Step 2.

7. If the reading is lower than specified, there is high resistance in the circuit. Check the ignition switch, battery cables, neutral safety switch, clutch engage switch, main harness connector, and the wiring between these components. Repair or replace defective parts.

8. Turn the ignition switch off.

Step 2—Coil Voltage Test in the Start Position

To test the voltage to the coil with the ignition switch in the START position, do the following:

1. Attach the (−) voltmeter lead to a good ground.

2. Connect the (+) voltmeter lead to the connector on the battery wire (see Fig. 11-1).

3. Have an assistant crank the engine over with the ignition switch.

4. Note the voltmeter reading. It should be within one volt of that of the battery. If it is, proceed to Step 3.

5. If the voltage drop is more than one volt, there is excessive resistance in the circuit. In this case, check the ignition switch, battery cables, neutral safety switch, clutch engage switch, main harness connector, and the wiring between these components. Make repairs or replacements as necessary.

6. Shut the ignition switch off, and plug in the battery connector at the distributor.

Step 3—Testing the Pickup Coil for Shorts

To check the pickup coil within the pole piece assembly for a short to ground, do the following:

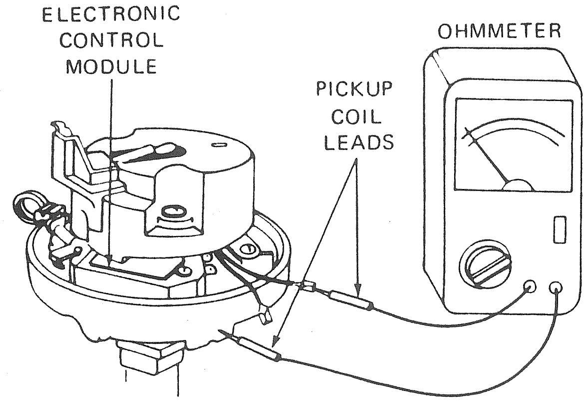


FIGURE 11-2
Checking the pickup coil for shorts.

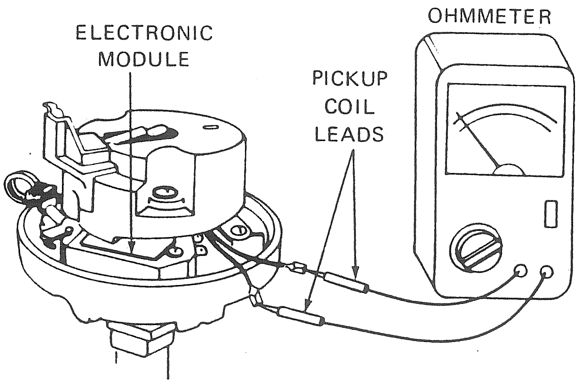


FIGURE 11-3
Testing pickup coil resistance.

1. Remove the distributor cap.

2. With the ignition switch off, disconnect the pickup coil leads from the ignition module (Fig. 11-2).

3. Connect one ohmmeter lead to a good ground on the distributor.

4. Touch the other lead to either of the pickup coil leads.

5. Note the ohmmeter reading. If it indicates infinity, go to Step 4.

6. If the ohmmeter shows continuity, the coil is shorted and requires replacement.

Step 4—Checking Pickup Coil Resistance

This process tests the resistance of the pickup coil within the distributor pole piece assembly. Use a vacuum pump to operate the vacuum advance and wiggle the wires during the test. Also, check the pickup resistance with the engine both hot and cold. To perform this test, do the following:

1. Set the ohmmeter to the R × 100 range.

2. With the ignition switch off, attach one ohmmeter lead to each of the pickup coil leads (Fig. 11-3).

3. Note the reading on the meter. If the resistance reading is steady and to specifications, proceed to Step 5.

4. If the reading fluctuates or is not to specifications, replace the pickup coil.

5. Plug the pickup coil leads into the module.

Step 5—Testing the Capacitor for Shorts

To check the capacitor within the distributor for a short circuit, do the following:

1. With the ignition switch off, remove the wire from the capacitor.

2. Set the ohmmeter to the R × 100 range.

3. Attach one ohmmeter lead to a good ground on the distributor.

4. Touch the other ohmmeter lead to the capacitor terminal (Fig. 11-4).

5. Note the ohmmeter reading closely. The meter needle should move a small amount and then settle on infinity. If it does, proceed to Step 6.

6. If the meter shows any constant reading other than infinity, the capacitor is shorted and requires replacement.

7. Plug in the capacitor lead.

Step 6—Checking Primary Coil Resistance

To test the resistance of the primary windings of the ignition coil within the cap assembly, do the following:

1. With the ignition switch off, remove the BATTERY and TACH leads from the cap terminals

2. Set the ohmmeter to the R × 1 scale.

3. Connect one ohmmeter lead to the TACH

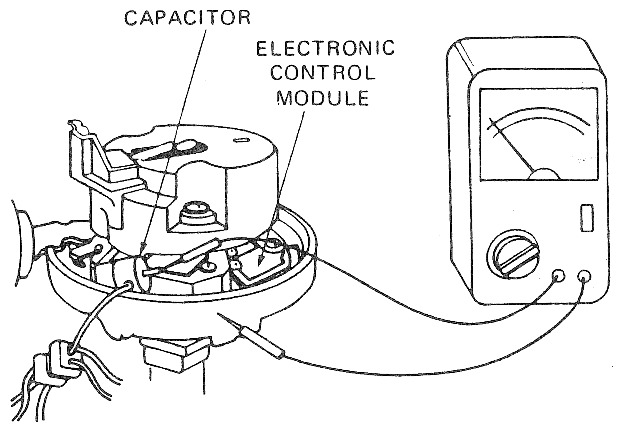


FIGURE 11-4
Checking the capacitor for shorts.

cap terminal and the other to the BATTERY terminal (Fig. 11-5).

4. Note the ohmmeter reading. If it is not to specifications, replace the coil assembly.

5. Remove the ohmmeter lead from the BATTERY terminal and attach it to the distributor GROUND terminal (see Fig. 11-5).

6. Note the ohmmeter reading. If the meter shows anything other than infinity, replace the coil.

7. If the meter shows infinity, go to Step 7.

Step 7—Testing Secondary Coil Resistance

To check the resistance of the secondary windings of the ignition coil against specifications, do the following:

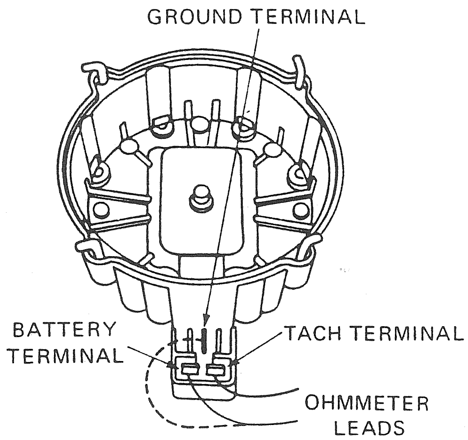


FIGURE 11-5
Testing primary coil resistance.

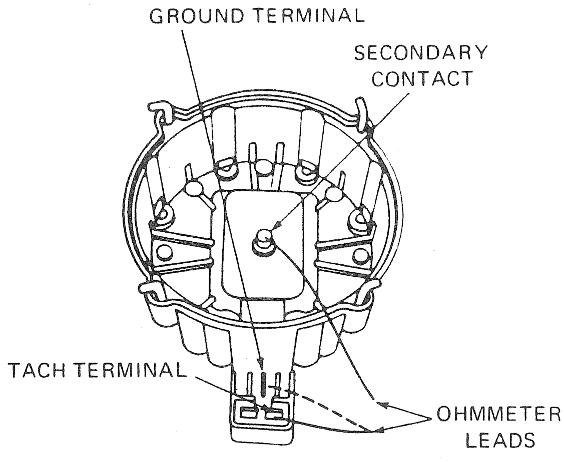


FIGURE 11-6
Checking secondary coil resistance.

1. Set the ohmmeter to an R × 1000 scale.

2. Connect one ohmmeter lead to the carbon brush (Fig. 11-6).

3. Touch the second ohmmeter lead first to the TACH and then to the GROUND terminal. Note the ohmmeter reading as you check each terminal.

4. If either or both of the readings is not to specifications, replace the coil assembly.

5. If the readings are within specifications, proceed to Step 8.

Step 8—Checking the Ignition Module

To test the serviceability of the distributor ignition module, do the following:

1. With the ignition switch off, disconnect all the leads from the ignition module and remove the module from the distributor.

2. Test the unit on a module tester. If the unit is found defective, replace it.

3. If a tester is not available, substitute the old unit with a serviceable module. If the engine now operates, replace the module.

4. Reinstall the distributor cap and plug in its ignition leads.

Testing the Pickup Coil with a Scope

This test can be used as an alternative to Steps 3 and 4 if you have an Allen "Smart" scope or its equivalent. The test itself checks the pickup coil op-

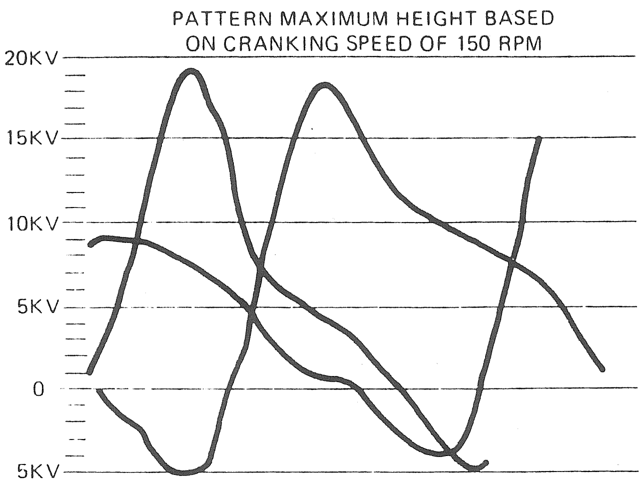


FIGURE 11-7
Testing pickup coil operation with a scope.

eration with the engine cranking over. To perform this test do the following:

1. Remove the distributor cap.

2. With the ignition switch off, remove the pickup coil leads from the module.

3. Connect the red test probe to the white pickup coil lead.

4. Attach the black test probe to the green pickup coil wire.

5. Set the scope for self-sweep operating mode.

6. Place the ohm scale selector on the × 10 position. The scope is now a 2.5 voltmeter using the left grid scale.

7. Crank the engine over using the ignition switch, while observing the scope screen.

8. If there is no scope pattern, replace the pickup coil

9. If there is an AC sweep pattern, as shown in Fig. 11-7, the pickup coil is satisfactory.

HEI Secondary Circuit Scope Tests

Secondary scope analysis is the best way to quickly determine the cause of poor engine performance due to a problem in the HEI system. The oscilloscope can check required voltage, required voltage under load, available voltage, and secondary circuit insulation and condition.

Figure 11-8 shows a comparison of a basic HEI secondary pattern to one for a conventional contact point system. Notice that the firing and the oscillations within the intermediate section of both the HEI and conventional systems appear about the same. However, the HEI firing lines will be higher for two reasons. First, the spark plug gaps for HEI-equipped vehicles have a wider gap. This will increase the required voltage and therefore the height of the firing line.

Second, the HEI system uses a much larger rotor gap than a conventional system. This will also increase the height of the firing line. This also means that a shorted plug or secondary wire will not have as short a firing line with HEI as it would with a conventional system. This is due to the greater voltage needed to bridge the rotor air gap.

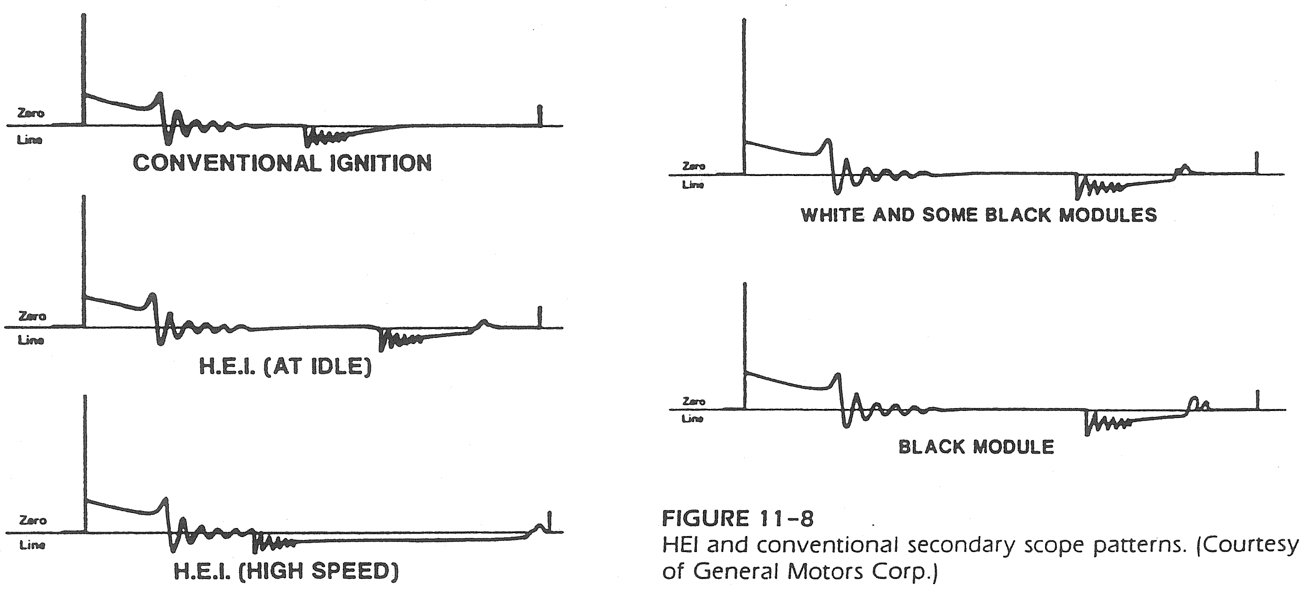


FIGURE 11-8
HEI and conventional secondary scope patterns. (Courtesy of General Motors Corp.)

There are a number of differences in what is actually occurring within the dwell section of the HEI pattern. For example, as the dwell period begins at the end of the intermediate section, the timer core teeth approach alignment with those of the pole piece. This signals the module to close the primary coil circuit. As current begins to flow, the series of oscillations, indicating the beginning of the dwell period, reflect the small voltage induction in the secondary windings.

In addition, note the voltage ripple near the end of the dwell line. The ripple, or oscillation, indicates that primary current has reached its maximum value before dropping slightly. The slight reduction in primary current flow occurs just as the timer core and pole piece teeth align, which signals the module to open the primary circuit.

Lastly, notice the difference in the length of the dwell periods between the two patterns. In the HEI system, dwell is electronically controlled and varies with engine speed.

If there is any deviation from what is shown in the HEI dwell and intermediate sections, the cause can be found using the steps outlined earlier in this section. Causes of malfunctions in the firing and spark lines can be diagnosed in the same way as outlined in Chapter 7, Section 7-2, Step 4.

11-3 TESTING A TYPICAL HEI, EST SYSTEM

There are quite a number of similarities between testing the basic HEI system and the combination HEI and electronic spark transfer system (EST). The reason for this is that the later system uses the HEI distributor but without the vacuum and centrifugal advance mechanisms. Their function is taken over by the ECM.

If an engine with an integral HEI distributor and an EST system will not start, locate the cause of the problem by following the steps below.

Step 1—Preliminary Tests

To determine if the no-start condition is due to a failure of the ignition system, do the following:

1. Carefully remove a spark plug cable.

2. Install the cable terminal over a spark tester, and connect to ground.

3. Have an assistant turn the engine over.

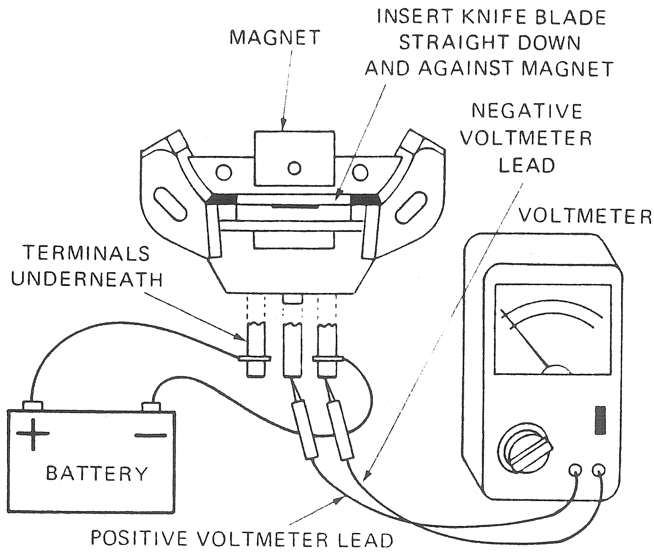


FIGURE 11-9
Testing the Hall effect switch.

4. Observe the tester for signs of a spark. If there is no spark, complete Steps 1 through 7 as outlined in Section 11-2.

5. If the system passes Steps 1 through 7, go to Step 2 below.

6. If there is a spark at the tester, proceed to Step 4.

7. Remove the tester and reconnect the cable to the spark plug.

Step 2—Checking the Hall-effect Switch

To test the serviceability of the Hall-effect switch, do the following:

1. With the ignition switch off, disconnect the three-wire connector from the Hall-effect switch.

2. Using jumper leads, connect a 12-volt battery to the Hall-effect switch terminals, as shown in Fig. 11-9.

3. Attach the leads of a voltmeter to the switch as indicated in Fig. 11-9. *Make sure the positive and negative jumper and voltmeter leads are connected properly.*

4. Insert a steel knife blade down between the switch and the magnet.

5. Note the reading on the voltmeter. It should read within 0.5 volt of that of the test battery.

6. Remove the knife and check the meter read-

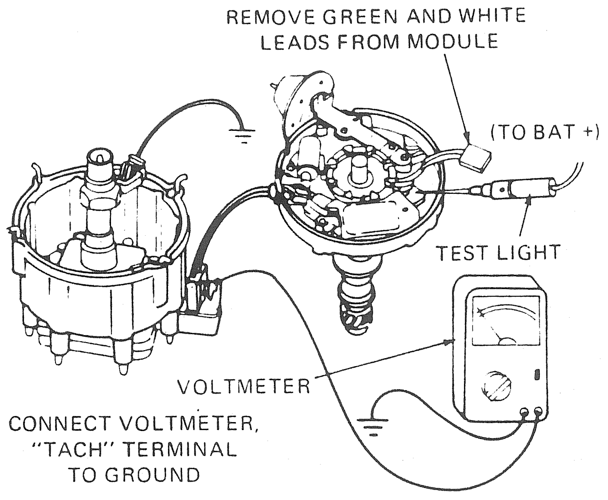


FIGURE 11-10
Ignition module test.

ing. It should now read less than 0.5 volt.

7. If either or both voltage readings are incorrect, replace the Hall-effect switch.

8. If the readings are satisfactory, proceed to Step 3.

9. Remove the test battery and voltmeter leads. Then plug in the Hall-effect switch harness connector.

Step 3—Ignition Module Test

To check the serviceability of the module while it is still inside the distributor, do the following:

1. With the ignition switch off, invert the spark tester as shown in Fig. 11-10 and install it into the coil terminal. Ground the tester with a jumper lead.

2. Remove the pickup coil leads from the module

3. Connect the (−) lead of the voltmeter to a good engine ground.

4. Attach the (+) lead to the TACH terminal of the distributor cap. Do not unplug the control module wires from the distributor cap.

5. Turn the ignition switch to the RUN position.

6. Attach one lead of a 12-volt test light to the (+) battery terminal.

7. While observing the voltmeter, momentarily touch the tip of the test light probe to the ignition module's Terminal P.

8. A voltage drop should occur when the test probe touches the terminal. If a voltage drop does not occur, inspect and repair the module ground screw.

9. Retest for a voltage drop. If it still does not occur, replace the control module.

10. Turn the ignition switch off and remove the test light and voltmeter.

11. Plug in the pickup coil leads to the module.

12. If the voltage drop is okay, and there is still no spark at the tester during cranking, proceed to Step 4.

Step 4—EST System Test

To check EST signal input to the module from the ECM, do the following:

1. With the ignition switch off, unplug the four-terminal EST connector at the distributor.

2. Crank the engine over with the ignition switch and check for an arc at the coil-mounted spark tester.

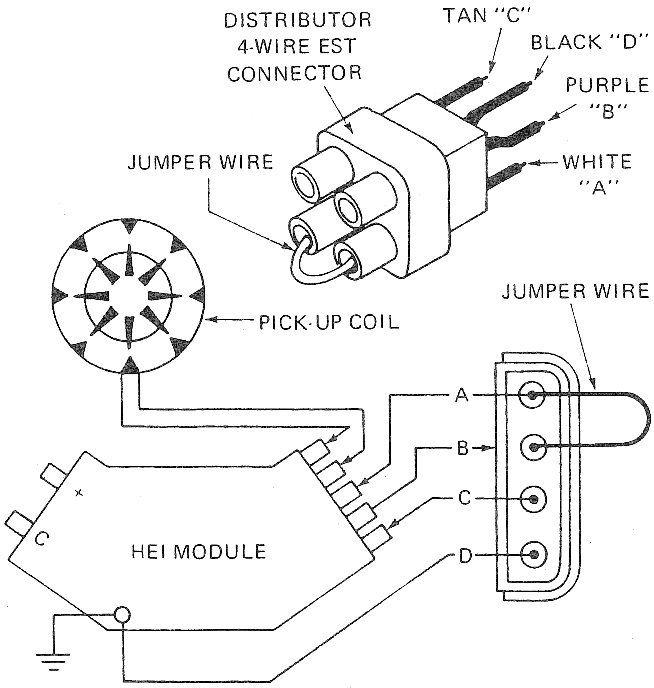


FIGURE 11-11
Test the EST system input to the distributor.

3. If a spark now occurs, attach a jumper wire between Terminals A and B on the distributor side of the EST connector (Fig. 11-11).

4. Remove the spark tester and reinstall the distributor cap.

5. Start the engine.

6. Ground the assembly line communications link (ALCL) test terminal under the dash. *Make certain you insert the jumper leads in the correct terminals for the year of the vehicle* (Fig. 11-12).

7. Connect a test light from the positive (+) terminal to Terminal C on the distributor side of the EST connector.

8. If the engine stops, again check all connections at the ignition module. Look for an open wire to Terminal E of the ignition module. If the wires and connections are okay, test the module and replace it if it is defective.

9. If the engine continues to operate, leave the test light connected but remove the jumper wire between Terminals A and B of the EST connector.

10. Now, if the engine continues to operate, check for an open wire or ground to the ignition module Terminal B, a short circuit between module Terminals R and E, or a faulty module.

11. If the engine stops when the jumper wire is removed, check for an incorrect ignition module, an open wire from the EST connector Terminal A to the ECM Terminal 12, an open wire or ground from the EST connector Terminals C to ECM Terminal 11, or poor connector contact at ECM Terminals 11 and 12. Repair or replace defective parts as necessary.

12. Remove the ground from the ALCL test terminal.

13. Plug in the EST connector to the distributor.

EST Performance Test

To check the performance of the EST system with a timing light, do the following:

1. With the engine shut off, connect a timing light by following the manufacturer's instructions.

2. Block all the vehicle wheels to prevent front or rear movement, and apply the parking brake.

3. Start the engine and place the transmission in park for automatic transmission vehicles or neutral for those with manual transmissions.

4. Start the engine. Check and note the amount of spark advance with the timing light.

5. Ground the ALCL test terminal.

6. Recheck the timing. If the engine timing changes from procedure 4, the EST system is operating properly.

7. If the timing does not change on vehicles equipped with automatic transmissions, shift the transmission into drive and observe the timing with the ALCL test terminal again grounded. If the engine timing now changes, the EST system is properly functioning. If the timing does not change, continue with the test sequence.

8. Shift the automatic transmission into park or the manual into neutral and then shut off the engine.

9. Carefully insert a pin through the wire to Terminal B of the MAP or VAC sensor (Fig. 11-13). *Make sure the pin does not contact an electrical ground.*

10. Connect the (−) terminal of the voltmeter to a good engine ground.

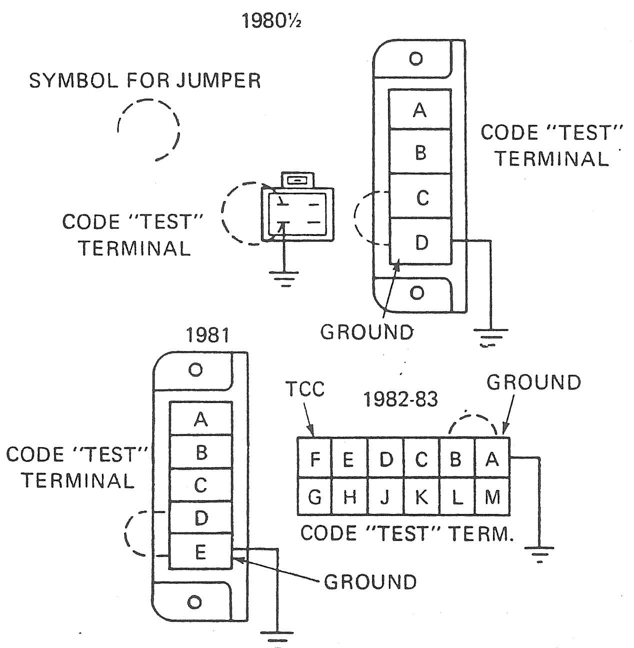


FIGURE 11-12
ALCL test terminals by vehicle model year.

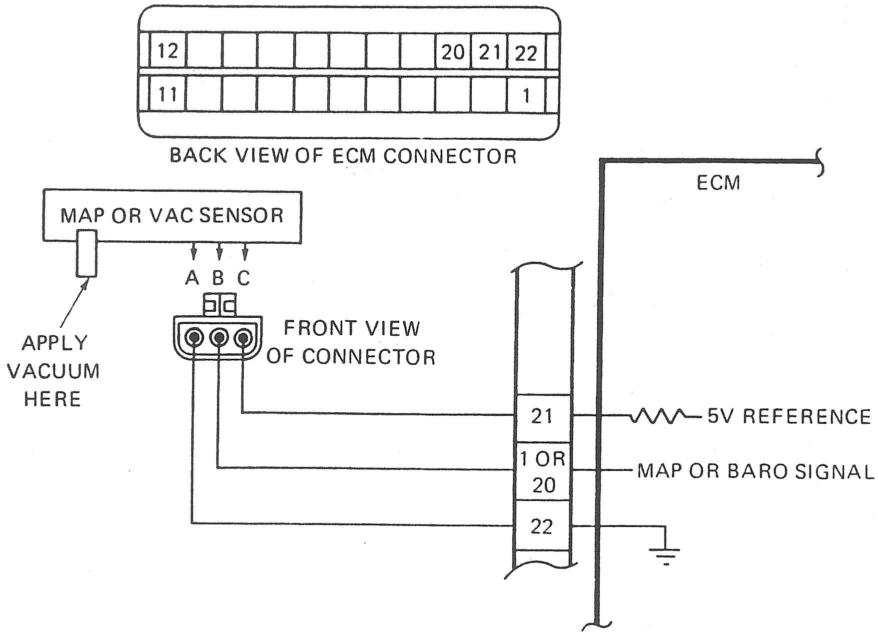


FIGURE 11-13
Checking MAP and VAC sensor voltage.

11. Attach the positive (+) voltmeter lead to the straight pin.

12. Start the engine.

13. Alternately remove and install the vacuum hose in the sensor while checking its output voltage on the meter. If voltage does not change, a problem exists in the MAP or VAC sensor or its circuit.

14. If the voltage changes, disconnect the park/neutral switch and complete procedures 4 through 6 again. If the timing now changes, replace or adjust the park/neutral switch.

15. If the timing still does not change, inspect for a grounded wire from the ECM Terminal H to the park/neutral switch.

11-4 TESTING A TYPICAL HEI, ESC SYSTEM

If an engine equipped with an HEI electronic spark control (ESC) system fails to start, remove a plug cable and attach it to a spark tester. Then, crank the engine over with the ignition switch. If there is no arc at the spark tester, use the troubleshooting steps outlined below to locate the cause of the problem.

Step 1—Start Failure Test

To check the supply voltage at the ESC controller against specifications, do the following:

1. With the ignition switch off, remove the ten-pin connector from the ESC controller.

2. Touch the (−) voltmeter lead to Terminal K of the connector (Fig. 11-14).

3. Touch the (+) voltmeter lead to the Terminal F of the connector.

4. Turn the ignition switch on and note the voltage reading. The reading should be seven volts or higher.

5. If the reading is under seven volts, check for a damaged wire between pin F and the ignition switch. Repair and replace damaged parts as necessary.

6. If the voltage is to specifications, proceed to Step 2.

Step 2—Checking the Distributor Harness

To test the wiring from the distributor to the ESC controller for continuity, do the following:

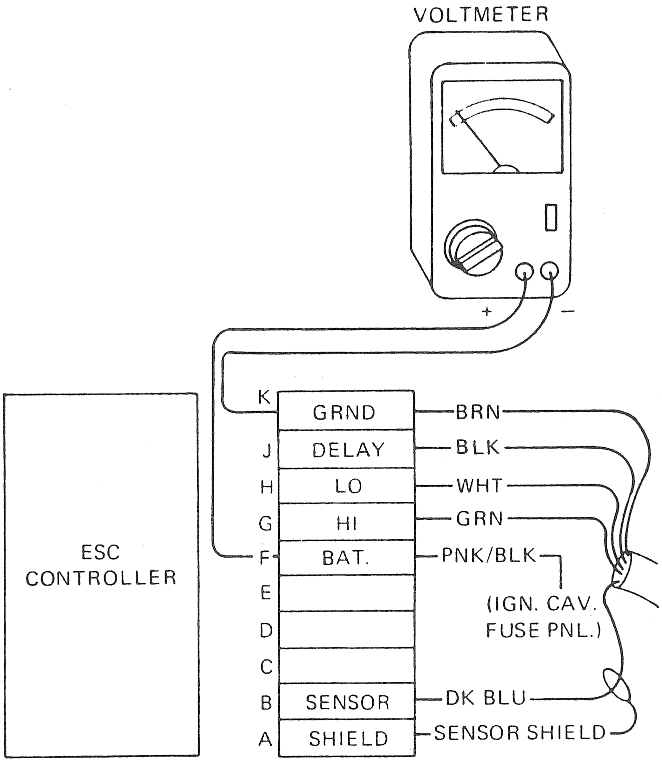


FIGURE 11-14
Testing the supply voltage at the ESC connector.

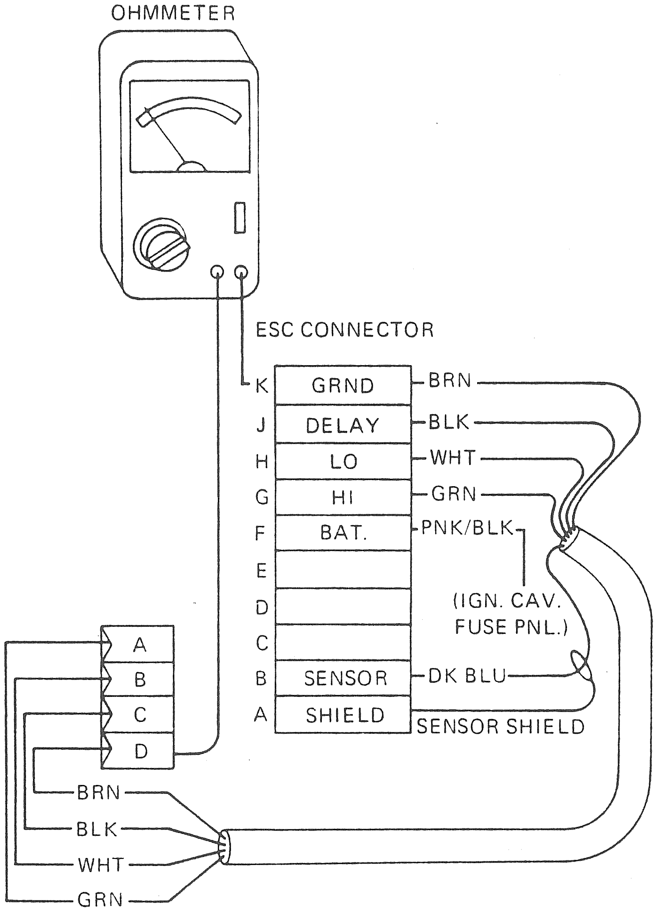


FIGURE 11-15
Checking the distributor-to-controller harness for continuity.

1. With the ignition switch off, remove the four-pin connector from the distributor.

2. Set the ohmmeter to the R × 1 scale.

3. Touch one ohmmeter lead to Pin K of the ESC connector and the other to Terminal D of the distributor connector (Fig. 11-15). Note and record the ohmmeter reading.

4. Touch one ohmmeter lead to Pin J of the ESC connector and the other to Terminal A of the distributor connector. Note and record the reading.

5. Touch one ohmmeter lead to Pin H of the ESC connector and the other to Terminal B of the distributor connector. Note and record the reading.

6. Touch one ohmmeter lead to Pin G of the ESC connector and the other to Terminal C of the distributor connector. Note and record the reading.

7. All of the readings should indicate continuity. If any do not, repair or replace the wiring harness between the distributor and the ESC controller.

8. Plug in the ESC harness connector at the controller.

9. If all the wires showed continuity, go to Step 3.

Step 3—Testing Coil Run Voltage

To test the voltage at the coil with the ignition switch in the RUN position, do the following:

1. With the ignition switch off, connect Terminals A and C of the distributor harness connector with a jumper wire (Fig. 11-16).

2. Disconnect the battery wire from the HEI distributor.

3. Attach the (−) voltmeter lead to a good engine ground.

4. Connect the (+) voltmeter lead to the connector on the battery wire.

5. Turn the ignition switch to the RUN position, and note the reading on the voltmeter.

6. If the reading is within one volt of battery voltage, proceed to Step 4.

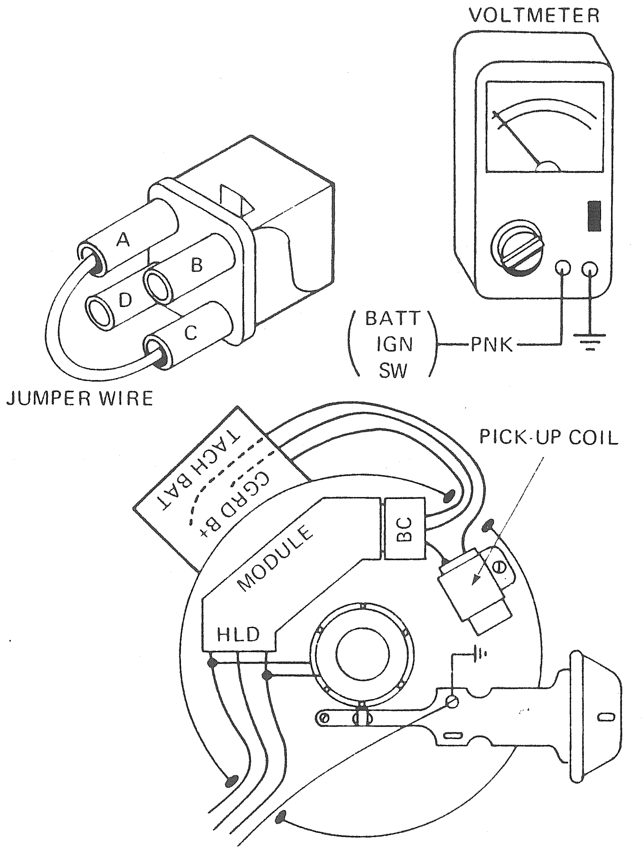


FIGURE 11-16
Testing for run voltage at the distributor harness connector.

7. If the reading is not within one volt, there is high resistance in the circuit. In this case, check the ignition switch, battery cables, neutral safety switch, main harness connectors, and the wiring between these components. Repair or replace defective parts as necessary.

Step 4—Checking Coil Start Voltage

To check the voltage at the coil with the ignition switch in the START position, do the following:

1. With the ignition switch off, connect Terminals A and C of the four-pin connector with a jumper wire (see Fig. 11-16).

2. Attach the (−) voltmeter lead to a good engine ground.

3. Connect the (+) voltmeter lead to the disconnected distributor battery wire.

4. Turn the ignition switch to the START position and note the reading on the voltmeter.

5. If the reading is within one volt of battery voltage, proceed to Step 5.

6. If the reading is not within one volt of that of the battery, there is high resistance in the circuit. In this situation, check the ignition switch, battery cables, neutral safety switch, main harness connector, and wiring between these components. Repair or replace any defective parts.

7. Turn the ignition switch off and plug in both the distributor battery and four-pin connectors.

Step 5—Pickup Coil Short and Resistance Tests

To determine if the pickup coil within the distributor has the correct resistance or is shorted out, follow Steps 3 and 4 as outlined under Section 11-2. If the pickup coil passes these tests, proceed to Step 6.

Step 6—Checking the Ignition Module

To test the serviceability of the module while it is still inside the distributor, do the following:

1. With the ignition switch off, invert the spark tester, as shown in Fig. 11-17, and install it into the coil terminal. Next, ground the tester with a jumper lead.

2. Disconnect the four-pin connector from the distributor.

3. Install a jumper wire between Terminals A and C of the four-pin connector.

4. Disconnect the pickup coil leads from the control module. Do not unplug the module wires from the distributor cap.

5. Attach the (−) voltmeter lead to a good engine ground.

6. Connect the (+) voltmeter lead to the TACH terminal of the distributor cap.

7. Turn the ignition switch to the RUN position.

8. Attach the lead of a test light to the (+) battery terminal.

9. Watch the voltmeter carefully as you touch the test light probe momentarily to the ignition module Terminal D.

10. If a voltage drop occurs, go to Step 7.

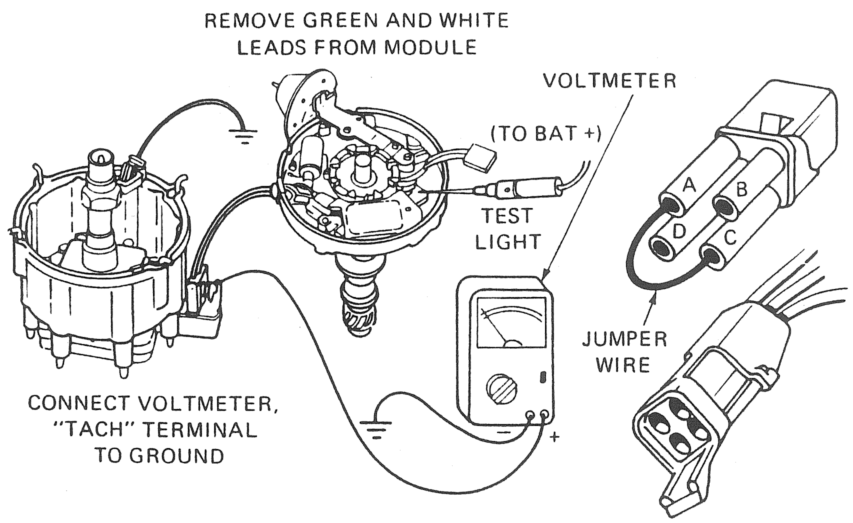


FIGURE 11-17
Checking the ignition module.

11. If there is no voltage drop, inspect and repair the module ground screw.

12. Perform the test again. If there is still no voltage drop, replace the ignition module.

13. Turn the ignition switch off.

Step 7—Testing the ESC Controller

To test the serviceability of the ESC controller, do the following:

1. Check to make sure the jumper wire is still in place between Terminals A and C of the four-way distributor connector (see Fig. 11-17).

2. Attempt to start the engine.

3. If the engine now starts, only operate it at idle. The fact the engine now runs indicates the ESC controller is defective and requires replacement.

4. Before replacing the controller, also perform Step 8.

5. Plug in the four-pin connector at the distributor.

Step 8—Checking Voltage at the ESC Controller

To check the voltage at the ESC controller with the ignition switch in the RUN position, do the following:

1. Make sure that all the vehicle accessories are turned off.

2. Start the engine.

3. With a voltmeter, test and record battery voltage.

4. With the ESC controller connector in place, connect the (−) lead of the voltmeter lead to Terminal K (Fig. 11-18).

5. Touch the (+) voltmeter lead to Terminal F.

6. Note the voltmeter reading. It should be within one volt of that noted in Procedure 3.

7. If the voltage is not to specifications, check the ignition switch wiring from the switch to the controller, and check the charging circuit. Repair or replace any defective parts.

ESC Operational Check

To check the operation of the ESC system, do the following:

1. Operate the engine until it reaches normal running temperature.

2. Shut off all vehicle accessories.

3. Following manufacturer's instructions, install a tachometer on the engine.

4. Set the carburetor fast idle cam on its high

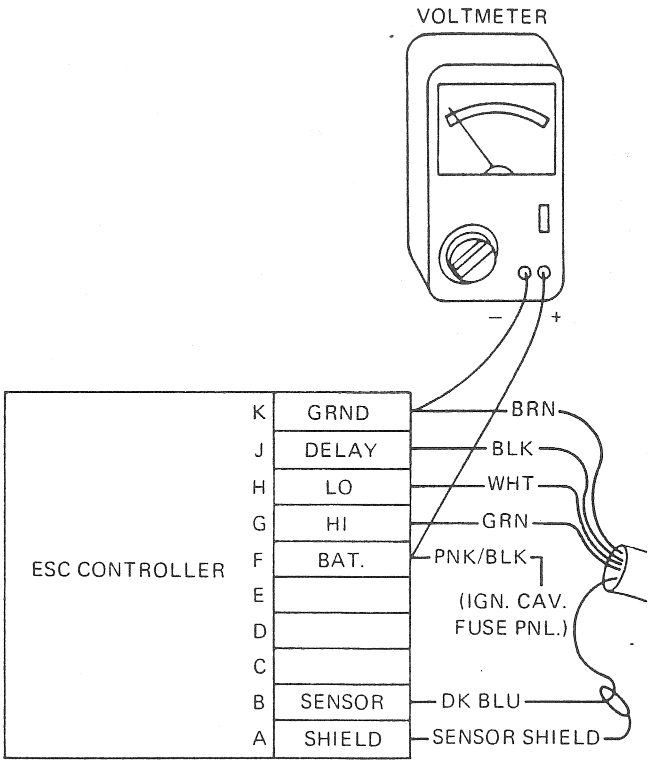


FIGURE 11-18
Testing EST controller run voltage.

step. At this point, engine speed must be above 1,800 rpm. Note and record the rpm.

5. Using a long socket extension or wrench, tap on the front area of the intake manifold near the detonation sensor (Fig. 11-19).

6. Note the engine speed on the tachometer. It should drop 200 rpm or more and return to its original speed within 20 seconds after the tapping stops.

7. If the engine speed does not drop or return as mentioned, test the detonation sensor and ESC system further.

8. Shut off the engine.

Testing the Resistance of the Detonation Sensor

To test the internal resistance of the detonation sensor against specifications, do the following:

1. Run the engine until it reaches its normal operating temperature.

2. Shut the engine off and remove the detonation sensor lead connector.

3. Set the ohmmeter to the R × 100 scale.

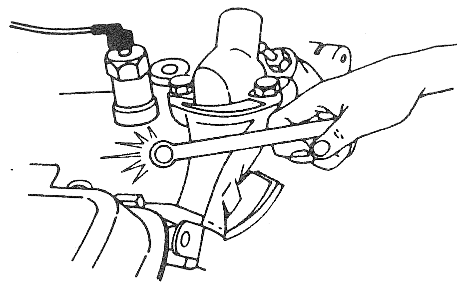


FIGURE 11-19
Tapping on the manifold to check ESC operation.

4. Attach the (−) lead of the ohmmeter to a good engine ground.

5. Touch the (+) voltmeter lead to the center conductor on the detonation sensor (Fig. 11-20).

6. Note the resistance reading on the ohmmeter. If the reading is not to specifications, replace the sensor.

7. If the reading is to specifications, proceed with the sensor wiring continuity check.

Checking Detonation Sensor Wiring Continuity

To check the continuity of the wire between the sensor and the controller, do the following:

1. With the ignition switch off, remove the ten-pin connector at the ESC controller.

2. Install a jumper wire between Terminals A and B of the ESC connector (Fig. 11-21).

3. Disassemble the detonation wiring connector.

4. Set the ohmmeter for the R × 1 scale.

5. Attach the (+) ohmmeter lead to the terminal on the controller side of the harness, indexing with the wire to the center sensor conductor.

6. Touch the (−) ohmmeter lead to the drain wire terminal at the connector.

7. Note the resistance on the ohmmeter. There should be continuity between the sensor wires. If continuity does not exist, repair or replace the wiring harness between the ESC controller and the detonation sensor.

8. If the detonation sensor and its wiring are found okay and the system still does not function, replace the ESC controller.

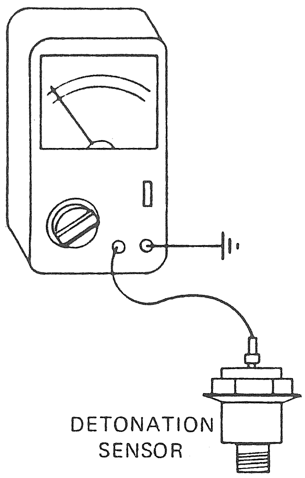


FIGURE 11-20
Checking detonation sensor resistance.

11-5 TESTING A TYPICAL DIS SYSTEM

The procedure outlined below is for locating the cause of a no-start condition on a 3.0-liter engine with a combination crankshaft sensor. The same process on other General Motors engines is somewhat different. *Always follow the service manual when testing the other systems, or damage to system components can result.*

During the following process, *you will need to use a DVOM with a 10-megohm or higher input impedance* and an unpowered test light. In addition, one step requires the use of a Weather-Pac terminal removal J-28742/BT8234-A and four special jumper leads with male and female terminals (Fig. 11-22). The General Motors part numbers for the terminals are 12014836 and 12014837.

Step 1—Initial Tests

If the engine cranks over but will not start, follow these steps to determine if the ignition system is at fault and, if so, the cause of the problem.

1. One at a time, connect the spark tester to the first, third, and fifth plug wires.

2. Crank the engine over and check for a spark at the tester. Repeat the process on the other two cylinders.

3. If there is no spark at the tester on any cylinder, inspect the system wiring connectors and the ECM and fuel pump fuses. If no problem exists in these areas, proceed to Step 2.

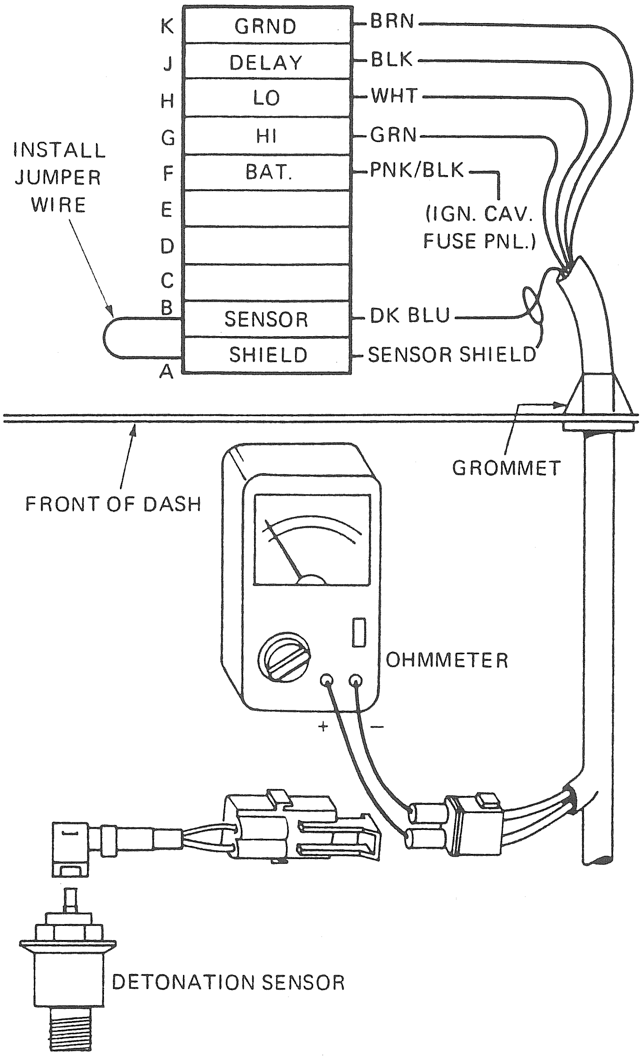


FIGURE 11-21
Testing the detonation sensor wiring for continuity.

Step 2—Checking ECM Reference Voltage

To test the reference voltage at the ECM harness connector, do the following:

1. With the ignition switch off, disconnect the ECM A-B connector.

2. Attach the (−) voltmeter lead to a good ground.

3. Touch the (+) voltmeter lead to Terminal B-5 of the ECM harness connector (Fig. 11-23).

4. Observe the voltmeter while cranking the engine over. The reading should be between one volt and seven volts and varying.

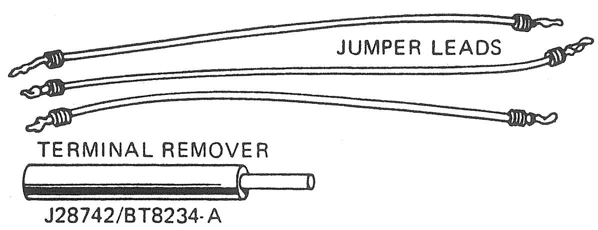


FIGURE 11-22
Weather-Pac terminal remover and jumper leads.

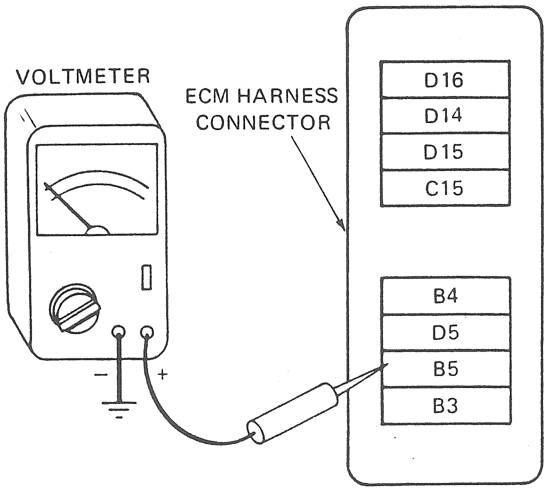


FIGURE 11-23
Checking ECM reference voltage.

5. If the reading is not to specifications, proceed to Step 5.

6. If the reading is okay, go to Step 3.

7. Reinstall the ECM A-B connector.

Step 3—Testing Voltage at the Coil

To check the supply voltage to the coil, do the following:

1. With the ignition switch off, remove the coil assembly screws and tilt back the assembly.

2. Connect the wire end of the test light to a good engine ground.

3. Turn the ignition switch on.

4. Touch the test light probe to the common blue coil feed wire (Fig. 11-24).

5. If the light burns, check the coil connections. If they are okay, replace the ignition module.

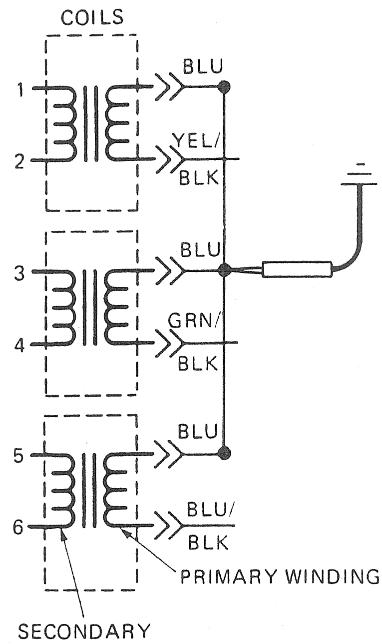


FIGURE 11-24
Testing coil supply voltage.

6. If the light does not burn, proceed to Step 4.

7. Turn the ignition switch off.

Step 4—Checking the ECM Input Voltage to the Ignition Module

To test the ECM supply voltage to the ignition module, do the following:

1. With the ignition off, disconnect the 14-pin connector at the C3 ignition module.

2. Connect the wire end of the test light to a good engine ground.

3. Turn the ignition switch on.

4. Touch the test light probe to Terminal M of the harness connector (Fig. 11-25).

5. If the light does not burn, check the 25-ampere ECM fuse. If it is okay, repair the opening in the feed wire to Terminal M.

6. If the light burns, inspect Terminal M. If it is found satisfactory, replace the ignition module.

7. Turn the ignition switch off.

8. Plug in the 14-pin connector at the module.

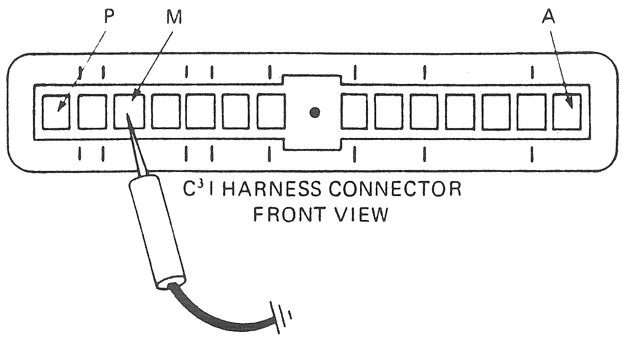


FIGURE 11-25
Checking module supply voltage.

Step 5—Testing Sensor SYNC Signal Voltage

To check the SYNC input signal at the ignition module, do the following:

1. Attach the (−) voltmeter lead to a good engine ground.

2. Connect the (+) voltmeter lead to Terminal K at the module (Fig. 11-26).

3. While observing the voltmeter reading, crank the engine over.

4. If the reading is one volt to nine volts, proceed to Step 9.

5. If the reading is not to specifications, go to Step 6.

6. Turn the ignition switch off.

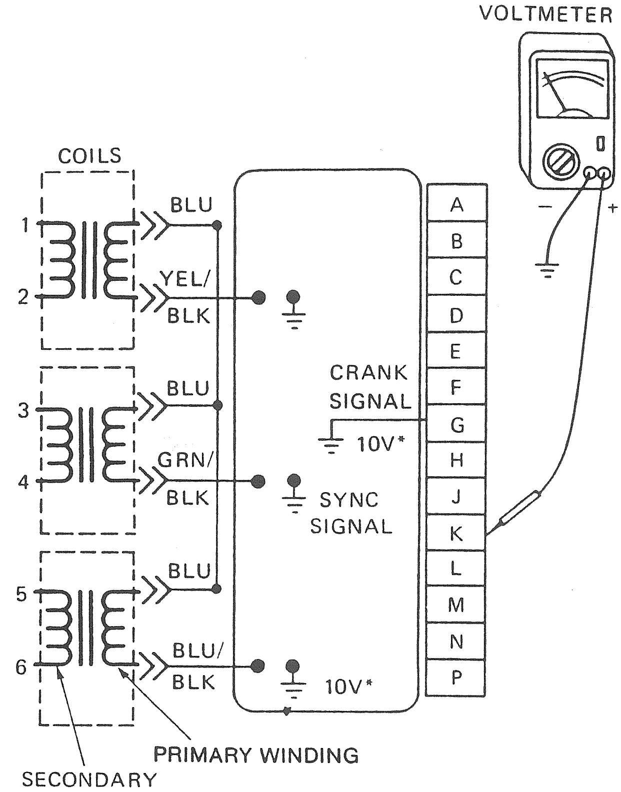


FIGURE 11-26
Testing the sensor SYNC voltage signal.

6. If the reading is between 5 and 11 volts, proceed to Step 8.

7. If the reading is not to specifications, check for an opening in the wire or Terminal H. If the wire and terminal are okay, go to Step 7.

Step 6—Checking Sensor Input Voltage

To test the sensor input voltage at its connector, do the following:

1. With the ignition switch off, unplug the crankshaft combination sensor's four-pin connector.

2. Connect the (−) voltmeter lead to a good engine ground.

3. Turn the ignition key on.

4. Touch the (+) voltmeter lead to Terminal A of the four-pin connector and observe the meter reading (Fig. 11-27). *Do not use a test light to check for voltage at Terminal A.*

5. Turn the ignition switch off.

Step 7—Testing ECM Sensor Supply Voltage to the Module

To check the sensor supply voltage from the ECM to the ignition module, do the following:

1. With the ignition switch off, unplug the 14-pin connector at the module.

2. Connect the wire end of a test light to a good engine ground.

3. Turn the ignition switch on.

4. Touch the probe of the test light to Terminal P of the harness connector (Fig. 11-28).

5. If the light does not burn, check the ten-ampere ECM fuse for serviceability. If it is okay, re-

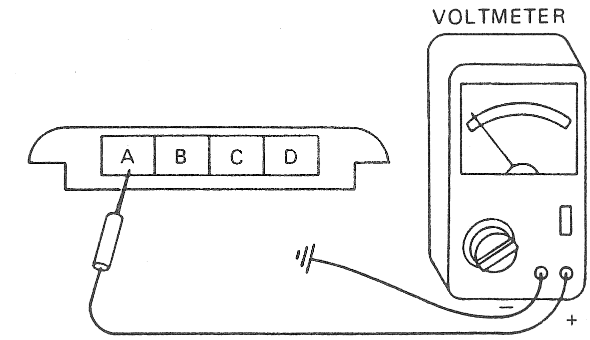


FIGURE 11-27
Checking sensor input voltage.

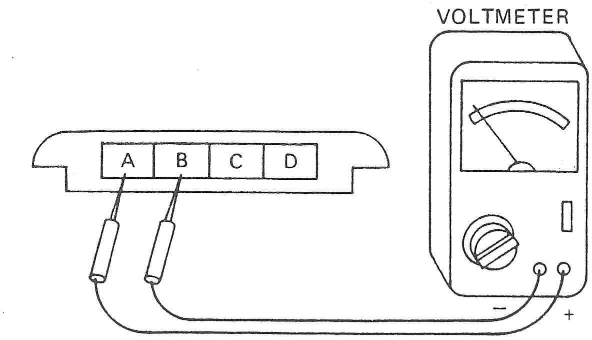


FIGURE 11-28
Testing ECM sensor supply voltage.

pair the open ignition wire to Terminal P.

6. If the light burns, check the connection at module Terminal P. If it is serviceable, replace the ignition module.

7. Turn the ignition switch off.

8. Plug in the 14-pin connector to the module.

Step 8—Checking Sensor Voltage Supply Circuit

To check the sensor supply circuit for continuity, do the following:

1. Connect the (−) lead of a voltmeter to Terminal B of the four-pin sensor connector.

2. Turn the ignition switch on.

3. Touch the (+) voltmeter lead to Terminal A of the four-pin connector (Fig. 11-29).

4. Read the voltage on the meter. If the reading is between five volts and 11 volts, go to Step 9.

5. Turn the ignition switch off.

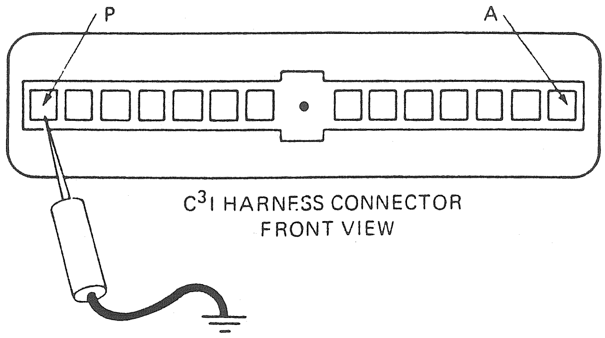


FIGURE 11-29
Checking the sensor supply voltage circuit.

6. If the reading is not to specifications, check for an opening in the wire and Terminal B of the harness. If both are satisfactory, check the connection at module Terminal B. If it is okay, replace the module.

Step 9—Testing Sensor Operation

To check the serviceability of the crankshaft combination sensor, do the following:

1. With the ignition switch off, use the Weather-Pac removal tool to take out the sensor and harness connector terminals.

2. Plug in the four special jumper leads into

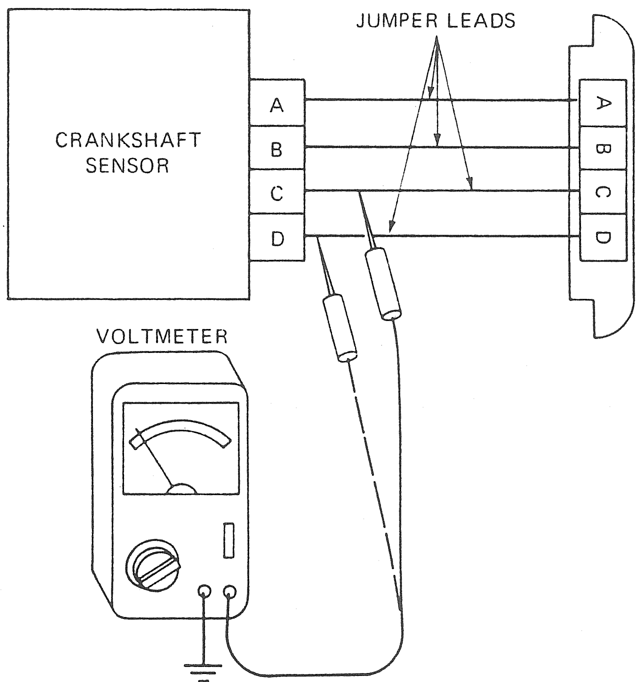


FIGURE 11-30
Testing sensor operation.

harness connector sockets A, B, C, and D. Next, plug the opposite end of each wire into its corresponding socket within the sensor connector.

3. Attach the (−) lead of the voltmeter to a good engine ground.

4. While cranking the engine, touch the (+) terminal of the voltmeter to the jumper lead attached to Terminal C of the sensor (Fig. 11-30).

5. Read the voltage on the meter. It should read a varying 0.7 volt to 9.0 volt.

6. While cranking the engine, touch the (+) terminal of the voltmeter to the jumper lead attached to Terminal D of the sensor.

7. Read the voltage on the meter. It should read a varying 1.0 volt to 9.0 volt.

8. If either or both the readings are not to specifications, replace the sensor.

9. If both the readings are within specifications and the engine will still not start, replace the ignition module.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete the statement or question, refer back to the section marked in brackets that covers the material.

SELF-CHECK

1. What special service items are necessary to test the DIS system [11-5]?
2. Why must you coat the base of the ignition module with a special compound during its installation [11-1]?
3. What equipment is used to operationally check the ESC system [11-4]?
4. What replaces the centrifugal and vacuum advance functions in the HEI, EST system [11-3]?
5. What are the two methods available to check the pickup coil for serviceability [11-2]?

REVIEW

1. In the troubleshooting sequence for a DIS no-start condition, when is it important *not* to use a test light [11-5]?
   a. when testing sensor input voltage
   b. when testing SYNC signal voltage
   c. both a and b
   d. neither a nor b
2. If an engine will not start, how do you test its HEI system for secondary voltage output [11-1]?
   Technician A replies through the use of a spark tester.
   Technician B says by removing a spark plug wire.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
3. If a 3.0-liter engine cranks over but will not start, how many crankshaft sensor tests should you make [11-5]?
   a. one
   b. two
   c. three
   d. four
4. Why lubricate the distributor coil-to-cap seal with silicone grease during installation [11-1]?
   Technician A states to prevent moisture contamination.
   Technician B says to prevent dust contamination.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
5. If there is no power to a DIS ignition circuit, how many fuses should you check for serviceability [11-5]?
   a. three

b. one
c. both a and b
d. neither a nor b

6. The HEI rotor is found to be burned through. What is the usual cause [11-1]?
Technician A says a lack of silicone grease on the coil seal.
Technician B states the lack of the special compound on the base of the module.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

7. Coil input RUN and START voltages are checked where in the HEI, ESC system [11-4]?
a. at the distributor harness connector
b. at the distributor battery connector
c. both a and b
d. neither a nor b

8. In regard to the HEI secondary scope pattern, what portion changes with engine speed [11-2]?
a. firing
b. dwell
c. spark line
d. intermediate oscillations

9. Test voltages for the ESC system must be within how many volts of battery voltage [11-4]?
a. one volt
b. five volts
c. both a and b
d. neither a nor b

10. For what reason will you find the HEI firing lines higher than those in a conventional system [11-2]?
Technician A replies it is due to wider spark plug gaps.
Technician B says it is due to a wider rotor air gap.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

11. The speed of an ESC equipped engine should drop _____ or more while tapping on the intake manifold [11-4]?
a. 50 rpm
b. 100 rpm
c. 150 rpm
d. 200 rpm

12. What equipment is necessary to test HEI pickup coil resistance [11-2]?
a. ohmmeter
b. voltmeter
c. vacuum pump
d. both a and c

13. In the EST system, what should the timing do with the ALCL test terminal grounded [11-3]?
Technician A says it should not change.
Technician B states it will change.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

14. What equipment is necessary to test a Hall-effect switch [11-3]?
a. a 12-volt battery and a voltmeter
b. a 12-volt battery and an ohmmeter
c. both a and b
d. neither a nor b

15. When testing the HEI, EST ignition module, where is the spark tester installed [11-3]?
Technician A states in the coil terminal.
Technician B replies on a spark plug cable.
Who is correct?
a. A only
b. B only
c. both a and b
d. neither a nor b

Chapter 12

COMPUTERIZED AIR INJECTION SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- explain the functions of the air injection system.
- describe the purpose and design of air injection system components.
- relate the design features and function of a typical Ford air injection system.
- describe the function and design of the components in a typical Chrysler air injection system.
- relate the design features and purpose of a typical General Motors air injection system.

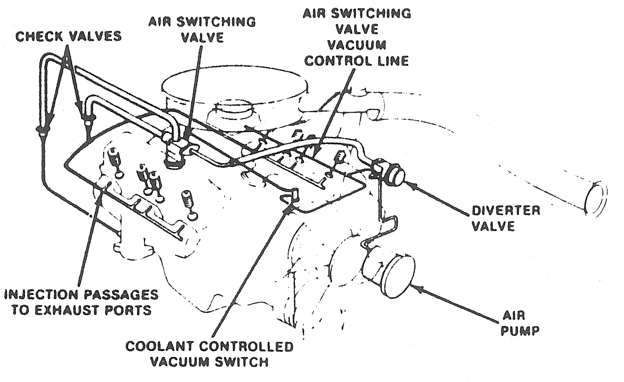


FIGURE 12-1
Typical air injection system. (Courtesy of Chrysler Motors Corp.)

Since the passage of the first California and federal emission control standards, manufacturers have extensively used various types of air injection systems (Fig. 12-1). There are several reasons for the popularity of air injection. First, the system is an external add-on unit that adapts to and functions well on most gasoline engines. Second, although the air pump does use up a small amount of engine power to drive it, and the system components take up space in the engine compartment, air injection does not affect the driveability of a vehicle like other emissions control equipment has in the past.

In the automobile industry, this system can have several different names, depending on the vehicle manufacturer. Some of the most common system names given include American Motors Air Guard, Chrysler Air Injection, Ford Thermactor, and General Motors Air Injection Reactor (AIR).

12-1 FUNCTION OF THE AIR INJECTION SYSTEM

Regardless of its name, the purpose of the system is the same no matter which vehicle it is on. However, there are functional and design differences between the systems used on early vehicles and those found on later designs with dual-bed catalytic converters.

System Function Before Dual-Bed Converters

The function of a basic air injection system is to introduce fresh air, with its oxygen content, into the hot exhaust of an operating engine. This action causes further burning, or oxidation, of the hydrocarbons (HC) and carbon monoxide (CO) remaining in the exhaust gases. During the process, the injected oxygen combines with the hydrocarbons to produce water (H_2O), usually in a vapor form, and with the carbon monoxide to form carbon dioxide (CO_2). As a result, the system is very effective in lowering both HC and CO emissions from any type of gasoline engine.

In some engine configurations, the air injection system directs the air into the exhaust manifold. In others, the system forces the air into the exhaust ports of the cylinder head. In either case, the end result is the same. Finally, on vehicles with single-bed catalytic converters, air flow from the system also provides the necessary oxygen content for this unit to continue oxidizing HC and CO emissions. The catalytic converter can then further reduce the levels of HC and CO from a vehicle.

System Function with a Dual-Bed Converter

When used with a dual-bed catalytic converter, the basic function of the air injection system remains the same. That is, the system forces a quantity of fresh air into the exhaust system. The main difference between the early and later designs is that when air injection is used with a dual-bed converter, the system can direct the air flow into different locations.

During cold engine operation, for example, the injection system supplies air to the upstream location (Fig. 12-2). This provides additional oxygen to begin further burning of the HC and CO compounds (that are normally higher at lower engine temperatures) either within the head or exhaust manifold. In reality, the head or exhaust manifold is the only warm area in which the oxidation could take place when the engine is cold, except for the combustion chambers.

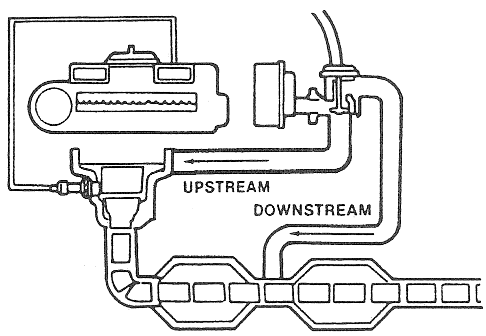


FIGURE 12-2
Air injection system used with a dual-bed converter. (Courtesy of Chrysler Motors Corp.)

The additional burning of the HC and CO emissions raises the temperatures within the exhaust system and causes the dual-bed converter to warm up faster. When the air of the injection system enters the upstream location, the dual-bed converter acts only to further reduce HC and CO compounds in the exhaust.

As the engine warms up to normal operating temperature, injecting air upstream would tend to increase nitrogen oxide (NO_x) emissions. This is not a big problem during engine warm-up because NO_x levels produced by a cold engine are not very high. But after the engine warms up, the pumping of the air into the upstream area makes it difficult for the front converter section to perform its function of reducing NO_x emissions.

Therefore, when the engine reaches normal operating temperature, a valve within the system switches the air from the upstream to the downstream location, or to the rear of the dual-bed converter. This injected air now continues the oxidation process on any remaining HC and CO compounds within the exhaust gases.

There is another reason on computer-controlled engines for switching the air from the upstream to the downstream location. If the system continued to pump air into the upstream location after the engine reached normal operating temperature, its oxygen content would throw off the operation of the oxygen sensor. As a result, the sensor signal will indicate the excessive oxygen content, and the computer interprets it as a lean mixture. The computer would enrich the air/fuel mixture to compensate, thus increasing fuel consumption.

12-2 DESIGN OF A BASIC AIR INJECTION SYSTEM

A basic air injection system used on both domestic and imported vehicles consists of a number of components. These include an air pump, one or more check valves, injection manifolds and tubes, a diverter, and a relief valve. Although most of these components perform the same functions in all systems, their design and location on a given vehicle may be different.

Air Pump

The *air pump* supplies a high volume of air at low pressure to the system. The pump itself mounts

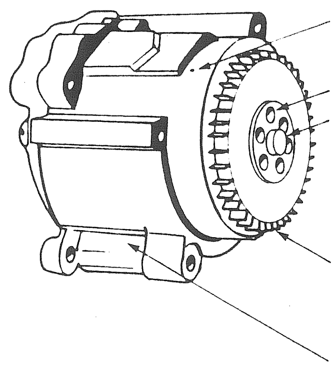


FIGURE 12-3
Typical air injection pump.

onto the front of the engine and is belt driven by the crankshaft. Pumps now are the two-vane design with a centrifugal filter fan (Fig. 12-3).

The centrifugal filter fan mounts on the forward end of the pump's rotor shaft and therefore turns at pump speed. This unit is not a true filter, but it does clean up the air as it enters the inlet port of the pump. This eliminates the need for a separate air filter, hose, and connections.

The centrifugal filter is nothing more than a vaned wheel that, when turning, actually opposes normal air entry into the pump's inlet port. This opposition is not sufficient to hamper the flow substantially. However, it causes the discharge of any foreign particles from the air before they can enter the pump and damage internal components.

In operation, the air enters the pump inlet by passing between the vanes of the filter (Fig. 12-4). These vanes are turning at a relatively high speed. Therefore, the vanes strike any heavier-than-air par-

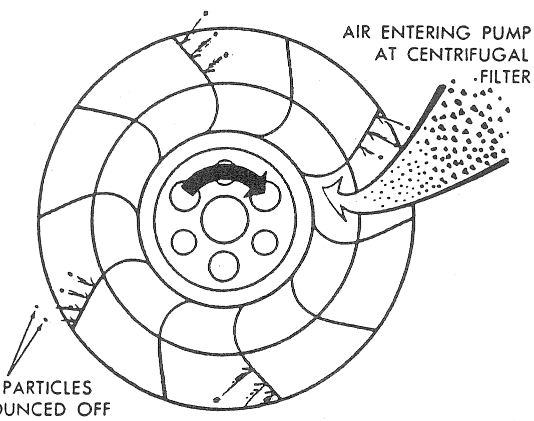


FIGURE 12-4
Operation of the centrifugal filter. (Courtesy of United Delco)

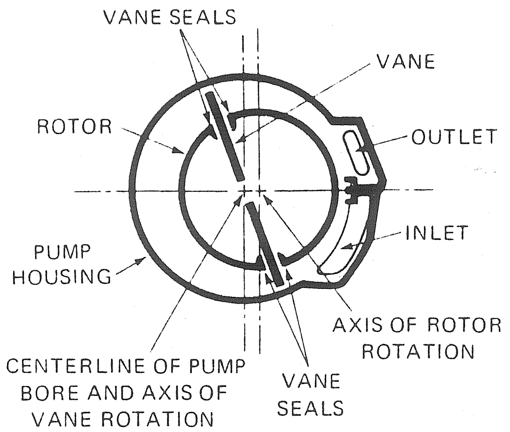


FIGURE 12-5
Construction schematic of a two-vane pump.

ticles attempting to enter the pump's inlet with the incoming air. The vanes throw them out and away from the pump. In other words, the vanes force the foreign particles to move out of the filter in an opposite direction to the incoming flow of air.

As mentioned, along with the filter fan, the pump has a set of vanes mounted on a rotor and shaft inside the pump housing (Fig. 12-5). These vanes ride in slits within the rotor and are 180 degrees apart. In addition, a set of seals (two per vane) provide sealing between the rotor and the vanes.

A pump pulley, through a shaft, drives the rotor, which turns on an axis that is different from the center line of the pump housing bore. The vanes, on the other hand, must turn about the center line of the same bore.

The vanes are in near constant contact with the bore of the housing as the rotor rotates. Consequently, the vanes always have to slide back and forth in the sealed rotor slits during pump operation. This action occurs because the vanes and rotor operate on different centers.

When the pump is operating, a vane moves past the inlet port. This has the effect of producing a vacuum on the port. Atmospheric pressure forces air through the centrifugal filter and into the vacuum formed at the pump inlet (Fig. 12-6a).

As the vane continues to turn within the housing bore, a second vane passes the inlet port (Fig. 12-6b). At this point, the air that previously entered the pump is now trapped between the two vanes. As the shaft continues to rotate, the vanes trap and carry this air into a smaller area of the chamber. This action compresses the air.

Continued rotation of the first vane carries the compressed air past the outlet port (Fig. 12-6c). Once this vane passes the outlet port, the compressed air has exhausted out of the port and into the rest of the injection system. Remember, although this discussion has covered only one pumping cycle, two of them are made by the pair of vanes during one complete revolution of the rotor.

Check Valve

Before the compressed air from the pump enters the exhaust ports or manifold, it must pass through one or more check valves. The *check valve* allows pressurized air to enter one of these areas but prevents hot, corrosive, exhaust gases from backing up into interconnecting hoses or the pump.

To perform this function, the assembly has a spring-loaded valve disc located inside the housing (Fig. 12-7). When air enters the inlet side of the housing, the disc moves off its seat. This allows the air to pass through the outlet side and into the system.

However, in the event of pump drive belt failure, abnormally high exhaust system pressure, or a ruptured hose, the spring and gas pressure close the valve disc. This prevents the exhaust gases from passing back through the valve.

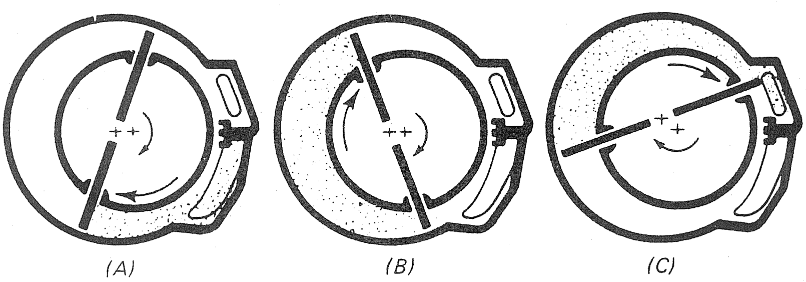


FIGURE 12-6
Pump operation.

Injection Manifolds and Tubes

The check valves mount onto an air manifold assembly (Fig. 12-8). The *air manifolds* distribute the incoming air to exhaust port locations. The upper illustrations in Fig. 12-8 show the manifold arrangement for a six-cylinder engine. The lower diagram shows the manifold on one side of a V-8 engine.

In both cases, the manifolds incorporate a number of *stainless steel tubes*—one for each engine cylinder. The tubes direct the injection air into the exhaust ports close to the exhaust valves near the exhaust manifold side of the port, or into the exhaust manifold itself, depending on the manufacturer's design.

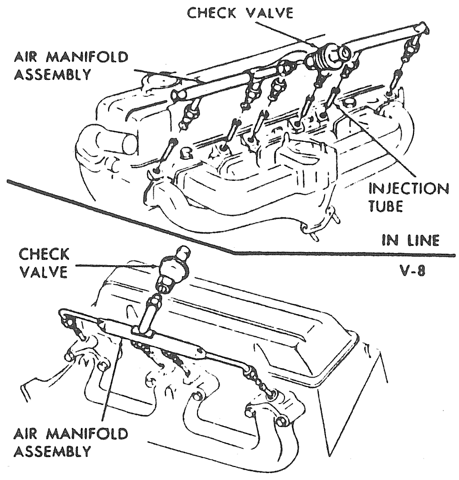


FIGURE 12-8
Air manifold design on a six-cylinder and a V-8 engine. (Courtesy of United Delco)

Diverter Valve

Every air injection system will have some form of diverter valve. This valve can be a separate unit connected to the pump by a hose or bolted to the pump itself (Fig. 12-9). In either case, the purpose of the *diverter valve* is to prevent a backfire in the exhaust system during engine deceleration.

When an engine decelerates with a closed throttle, there is a strong vacuum produced within the intake manifold. However, since the throttle valve is now in the closed position, it prevents sufficient air from filling the cylinders on their respective intake strokes. Under these conditions, the mixture that was pulled into the cylinder during throttle closing is too rich to completely burn within the combustion chambers.

Since a portion of the air/fuel mixture is not consumed during the following power strokes, a quantity of the charge exits the cylinders during the exhaust strokes. If at that point the air injection system continued to supply air to the manifold or ports, the oxygen would combine with the very hot mixture and explode, creating the backfire.

The diverter valve that fits between the pump and the air injection manifolds prevents the backfire by momentarily exhausting the air pump's output to the atmosphere. Therefore, additional air does not reach the exhaust during the stages of engine deceleration.

The diverter valve shown in Fig. 12-9 consists of a diaphragm and spring that control the operation of a double-acting metering valve. The upper and lower sides of the diaphragm form vacuum chambers, the upper one of which connects to the intake manifold via a hose.

The double-acting metering valve attaches to

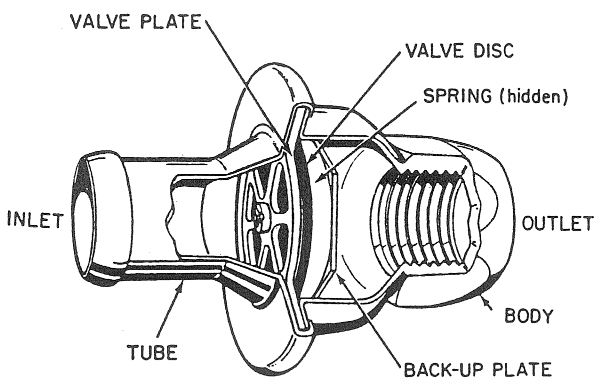


FIGURE 12-7
Design of a check valve. (Courtesy of United Delco)

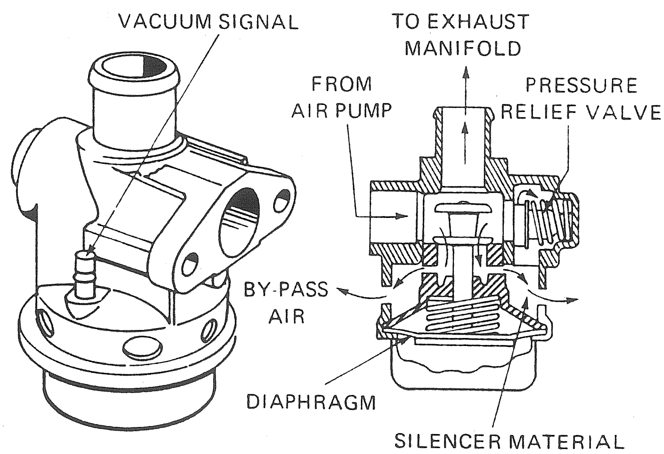


FIGURE 12-9
Diverter valve design and operation.

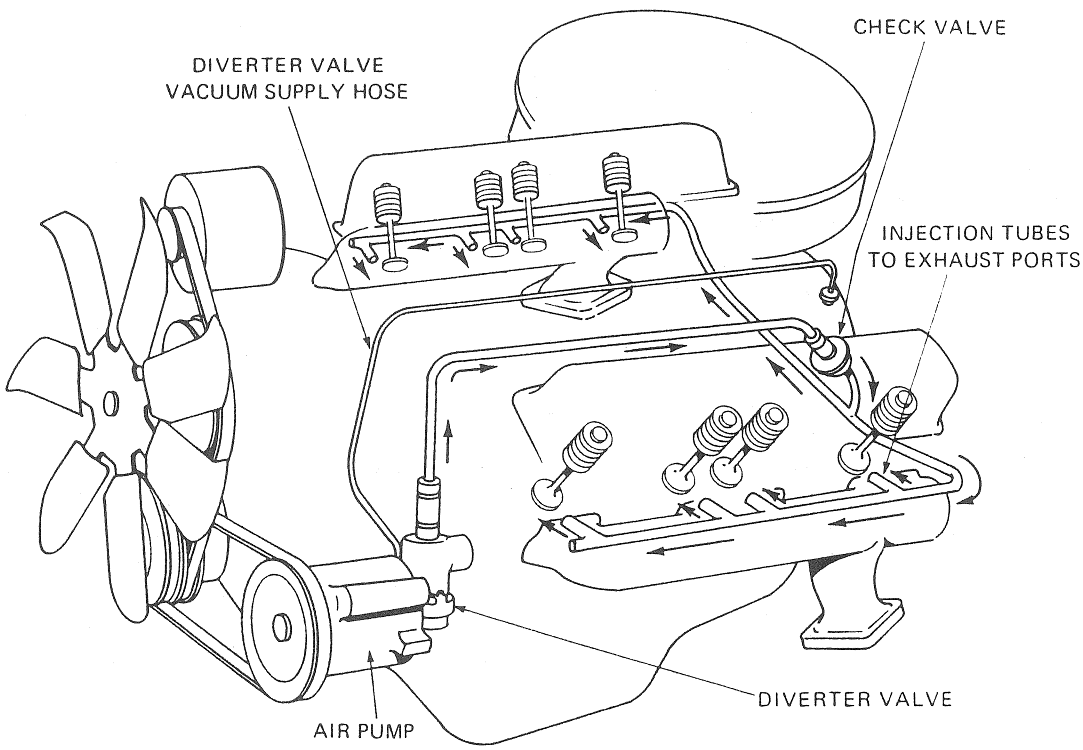


FIGURE 12-10
Air injection system operation.

the center of the diaphragm, which has an orifice incorporated into it. The spring holds the diaphragm and metering valve in the position shown in the illustration when the engine is operating. This occurs because vacuum from the manifold applies itself to both sides of the diaphragm via the orifice.

During deceleration, the sudden rise in intake manifold vacuum acts on the top of the diaphragm, first on its spring side. This causes the diaphragm to move the metering valve upward against its seat. This new valve position causes two reactions within the system. First, the upper portion of the valve seats to cut off normal pump air flow to the manifolds, as shown by the upper arrows.

Second, the lower portion of the metering valve unseats to momentarily bypass or divert the air from the pump through the silencer material to the atmosphere. Although the metering valve in the illustration is shown in the down position, the lower arrows indicate the path of air flow during deceleration.

The diversion of injected air flow only lasts for about one second to three seconds. This is due to the orifice hole built into the diaphragm assembly, which quickly equalizes the applied vacuum on both sides of the unit. As a result, the spring brings the diaphragm and metering valve back down to its normal operating position within a matter of seconds.

In effect, the diverter valve turns off the air supply to the manifolds suddenly in order to prevent a backfire. Then, the valve turns it back on gradually to once again start the oxidation process within the exhaust ports or manifolds.

Relief Valve

All injection systems using an air pump require a *relief valve.* This device controls pressure within the system by exhausting excessive pump output through the silencer and into the atmosphere at higher engine speeds. The diverter valve shown in Fig. 12-9 has the relief valve built into it. In early systems, the valve was built into the pump itself.

A typical relief valve assembly consists of a housing that encloses a preloaded spring, moveable valve, and valve seat. When pump pressure builds up to a pre-set amount, it forces the valve off its seat, compressing the preloaded spring. As a result, excess pump pressure exists through the silencer to the atmosphere.

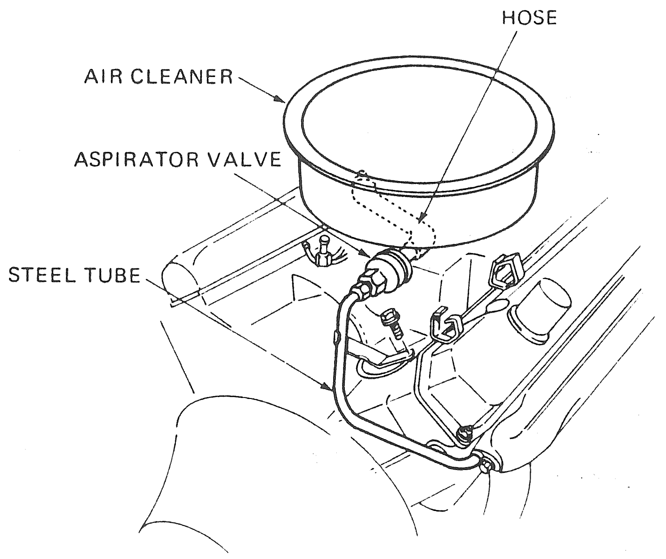


FIGURE 12-11
Design of an aspiration air injector system.

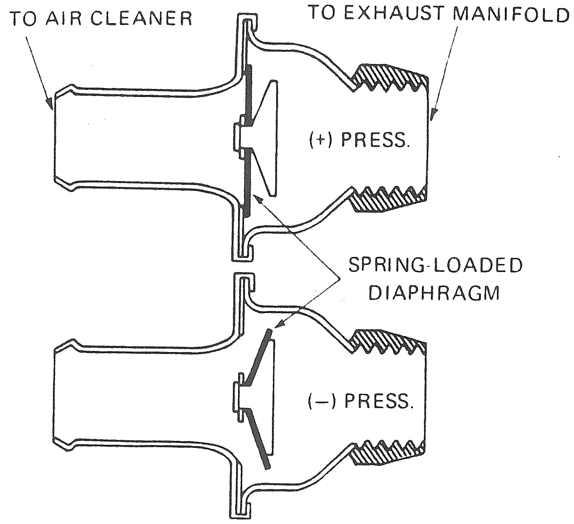


FIGURE 12-12
Design and operation of an aspirator valve.

When the pressure drops below the preloaded spring tension, the valve closes. This stops any further exhausting of pump pressure. In other words, preloaded spring tension determines at what air pressure the valve opens and therefore maximum system pressure during all phases of pump operation.

Injection System Operation

When the engine is running, the air pump displaces a large volume of low-pressure air. In the system shown in Fig. 12-10, this air first passes through the normally open diverter valve that is attached to the pump.

After passing through the diverter valve, the air moves via a hose or pipe to the check valve. The check valve is open any time the air injection pressure is higher than that within the exhaust system.

Once through the check valve, the air enters the injection manifolds. These units distribute the air to each of the tubes within the exhaust ports. If the air pressure during this time exceeds preloaded spring tension, the relief valve opens to reduce pump air pressure.

As the engine decelerates, the diverter valve closes. This action momentarily exhausts pump air into the atmosphere or to the air cleaner. This prevents a backfire in the exhaust system. Within one second to three seconds, the diverter valve opens again to allow normal operation of the system.

Aspirator-Type Air Injection Systems

There is a much simpler type of injection system used on both imported and domestic automobiles (Fig. 12-11). This system is known as either *aspirator-air, pulse air,* or *suction air injection.* No matter what names it goes by, the system performs the same function as the system just described but requires fewer components.

An aspirator injection system does not require a pump to force air into the manifolds. Instead, the system utilizes exhaust pressure pulsations to draw the air in from the atmosphere. Each time an exhaust valve closes, there is a period in which the exhaust manifold pressure drops below that of atmospheric. During these low-pressure or vacuum pulses, air from the clean side of the air cleaner moves into the exhaust manifolds.

The system shown in Fig. 12-11 consists of a steel tube, one-way aspirator valve, and a length of hose from the valve to the air cleaner. The steel tube transports the air from the aspirator valve to the exhaust manifold, where it is used to oxidize the HC and CO compounds.

Threaded into the upper end of the steel tube is the *aspirator valve* (Fig. 12-12). This device incorporates a spring-loaded diaphragm that acts as a one-way check valve. The diaphragm permits air to flow from the clean side of the air cleaner through itself, the steel tube, and into the exhaust manifold. However, it prevents exhaust gases from backing up through the system and into the air cleaner.

Aspirator System Operation

When an engine with an aspirator system is idling or operating at low speeds, the diaphragm valve opens and closes due to the pulsating negative and positive pressures within the exhaust system (Fig. 12–12a). In other words, the diaphragm valve opens each time there is a low-pressure (vacuum) pulse. This occurs every time an exhaust valve closes. With the valve open, atmospheric pressure forces fresh air from the air cleaner, through the aspirator valve and steel tube, and into the exhaust manifold.

At high engine rpm, when exhaust gas pressure is above that of the atmosphere, the spring closes the diaphragm valve (Fig. 12–12b). The unit now acts as a one-way check valve that prevents exhaust gases from backing up into the air cleaner.

This can occur at higher engine speeds because the exhaust vacuum pulses follow each other too rapidly for the valve to respond by opening. Consequently, the internal valve spring just keeps the diaphragm closed. As a result, no fresh air enters the exhaust manifolds during these periods, and exhaust gases will not flow back into the air cleaner.

12-3 TYPICAL FORD COMPUTERIZED AIR INJECTION

As mentioned, Ford calls its basic air injection system *Thermactor.* When Thermactor is connected into an exhaust system with a dual-bed catalytic converter, additional components are necessary to control air switching from the upstream to downstream locations. Moreover, the design and number of additional components vary somewhat with different engine and vehicle configurations, and depending on whether air switching is automatically or electronically controlled. This section discusses Ford's Managed Thermactor Air (MTA), which is used with EEC-III on 5.0-liter central fuel injection (CFI) engines (Fig. 12–13).

The MTA system illustrated has a number of familiar components. These include the pump and the relief and air check valves. Since the design and function of these parts are similar to those covered in Section 12-2, this section will discuss only those components that are new—the dual-bed converter, the air control valve, the air diverter solenoids, and the electronic control assembly (ECA).

Dual-bed Catalytic Converter

A *dual-bed, three way catalyst (TWC) converter* is shown in Fig. 12–14. This converter not only oxidizes HC and CO emissions but also reduces NO_x as well.

To do this, the front half, or bed, of the converter (close to the inlet) has a reduction-oxidation catalyst. This portion of the converter has a *monolithic substrate* with a *rhodium and platinum catalyst.*

The rear bed of the converter has only a platinum catalyst. Its function is to further oxidize any remaining HC and CO emissions within the exhaust.

Notice in Fig. 12–14 the mid-bed air port. This is the downstream location for the air from the Thermactor system. The air is used by the rear-bed catalyst to oxidize the HC and CO compounds.

In operation, the front and rear beds operate to oxidize HC and CO compounds during engine warm-up and at normal operating temperature. With the engine warmed up, the rhodium catalyst of the front bed also reduces NO_x by removing oxygen from it.

During the engine warm-up period, Thermactor air is directed upstream only. This aids in oxidation of the HC and CO compounds within the manifolds and front half of the converter.

At normal operating temperature, the air is switched to the rear half (1) to allow the front bed to reduce NO_x levels, (2) to supply enough air to the rear bed to permit continued oxidizing of the remaining HC and CO compounds, and (3) to prevent oxygen sensor malfunction.

Air Control Valve

The *air control valve* of this MTA system is part of a combination valve (see Figs.12–13 and 12–15). The *combination valve* consists of the pressure relief, bypass, and diverter valves. The pressure relief valve is similar in design and operation to the one discussed in Section 12-2.

The bypass and diverter valves both have diaphragm-operated, double-acting, metering valves. The upper bypass metering valve controls air flow between the pump and the diverter and relief valves. The lower diverter metering valve switches air flow to either the upstream or downstream locations.

Both the bypass and diverter diaphragms have

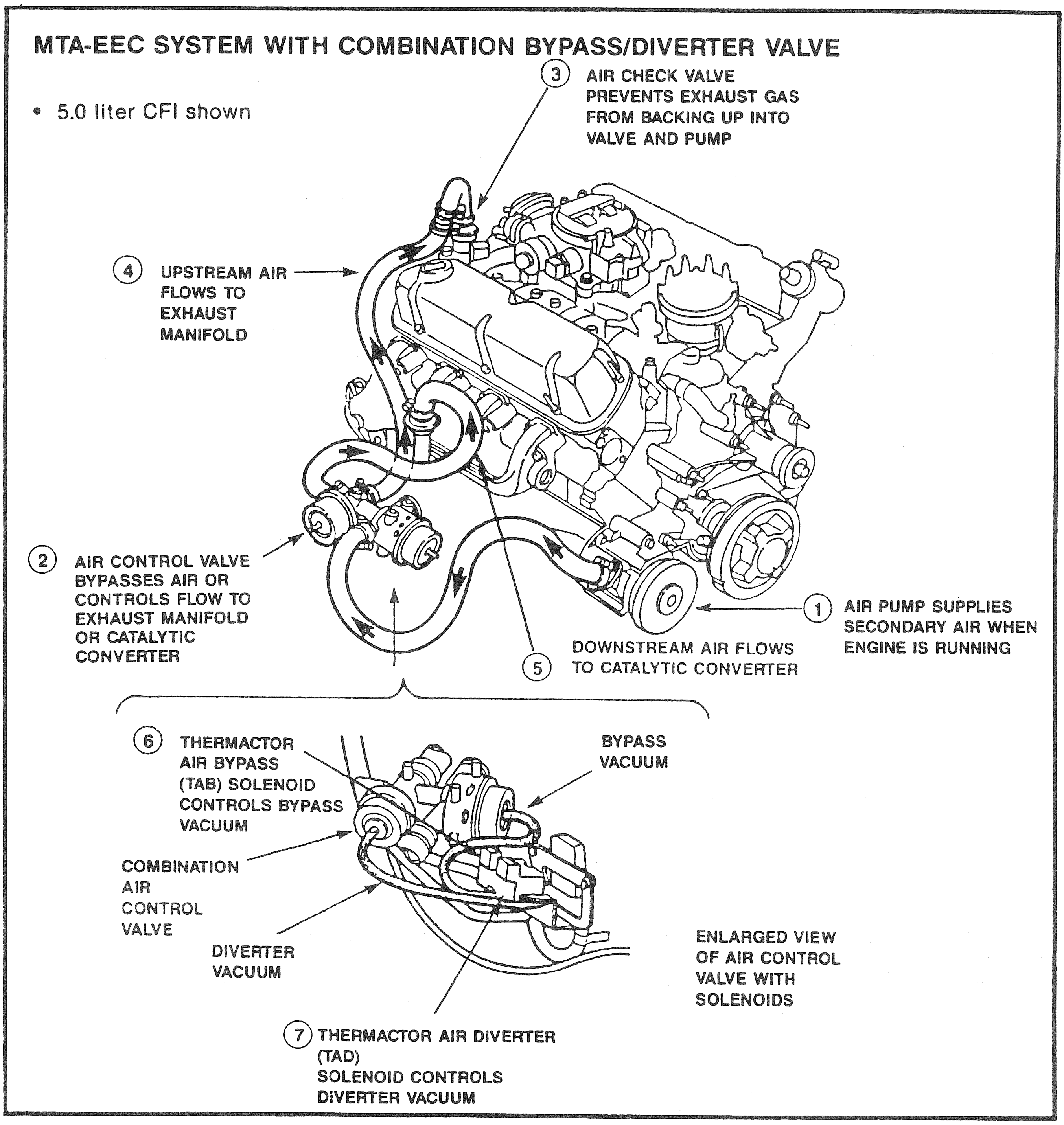


FIGURE 12-13
Ford's Managed Thermactor Air (MTA) system. (Courtesy of Ford Motor Co.)

THREE-WAY CATALYST (TWC) CONVERTER
- Controls HC, CO and NO_X
- Contains a COC element and a three way element
- Also called dual-bed converter

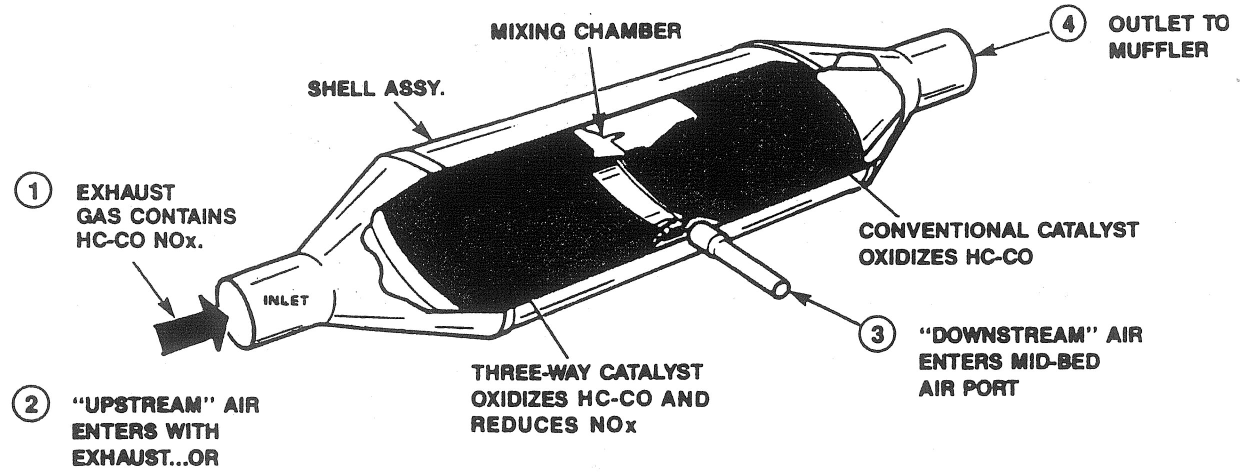


FIGURE 12-14
Dual-bed, three-way catalytic converter. (Courtesy of Ford Motor Co.)

calibrated springs and are enclosed in sealed housings connected to an intake manifold vacuum source. However, two solenoids control the engine vacuum supply to the diaphragms.

Solenoids

This MTA system uses two electromechanical vacuum solenoids (see Figs. 12-13 and 12-16). One of

FUNCTIONAL SCHEMATIC: MTA-EEC SYSTEM WITH COMBINATION VALVE
- 5.0 liter CFI car shown

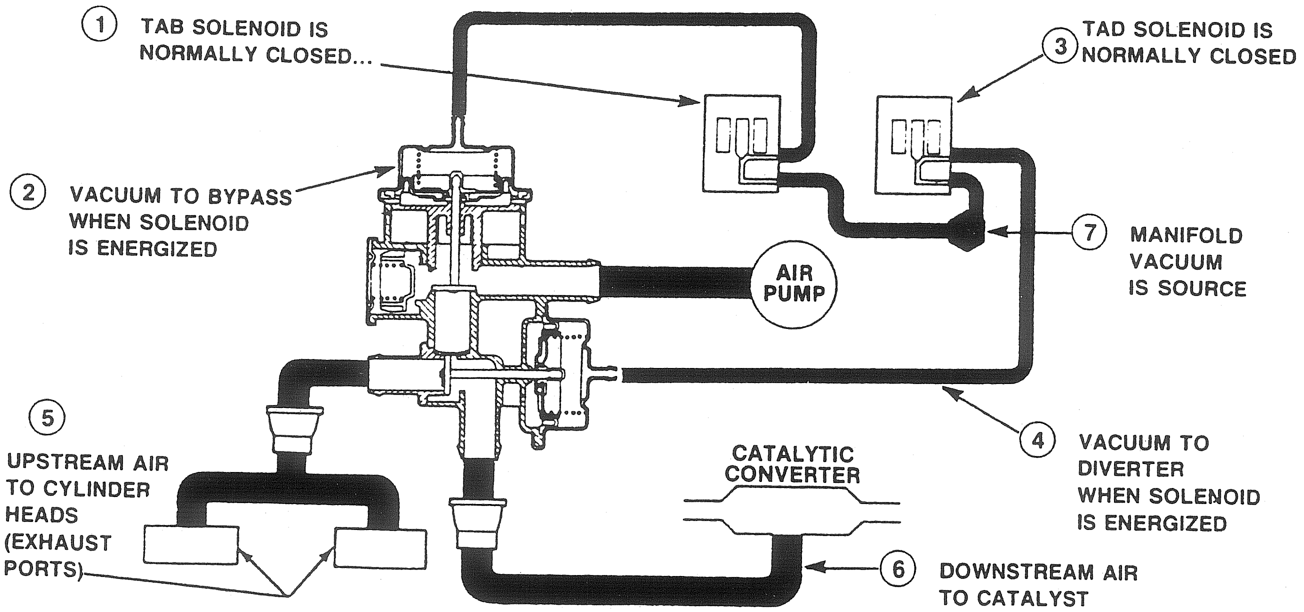


FIGURE 12-15
Schematic of the MTA system. (Courtesy of Ford Motor Co.)

the solenoids is known as the *Thermactor Air Bypass (TAB)* while the other is called the *Thermactor Air Diverter (TAD).* The TAB solenoid controls a vacuum signal to the air bypass valve. The TAD solenoid regulates the vacuum signal to the diverter valve.

The solenoids themselves have the same design. Each unit, for example, incorporates an electrical solenoid that controls the operation of a normally closed integral vacuum valve. If the solenoid is energized, its integral valve opens to allow a manifold vacuum signal to enter the bypass or diverter valve. If power is cut off to the solenoid, its valve closes, cutting off the vacuum signal. The electronic control unit energizes the solenoids by providing them with a ground.

ECA

The *electronic control assembly (ECA)* monitors engine-operating conditions and determines the proper on/off time of the various engine controls. To perform this function, the ECA analyzes a number of input signals from the many engine sensors (Fig. 12-17). The primary input signals come from the *engine coolant temperature (ECT)* and *throttle position (TP)* sensors shown on the left of Fig. 12-17.

After calculating the correct operating sequence for a particular engine control, the ECA energizes the unit by providing a ground circuit. The ECA ground circuits for the TAB and TAD solenoids are shown on the right side of Fig. 12-17.

System Operation with Air Bypassed to Atmosphere

Figure 12-18 shows the operation of the system with Thermactor air bypassed to the atmosphere. This phase of operation is entered during cold engine starting, wide-open throttle engine operation, closed-throttle engine deceleration, and hot curb idle.

In this situation, the ECA *does not* ground either the TAB or TAD solenoids, so both of their vacuum valves remain closed. This action cuts off intake manifold vacuum to the bypass and diverter valves.

The bypass valve spring pushes the diaphragm and its attached metering valve to the down position. This valve, in turn, blocks pump air flow to the diverter valve. As a result, when its pressure is high enough, air passes to the atmosphere via the relief valve.

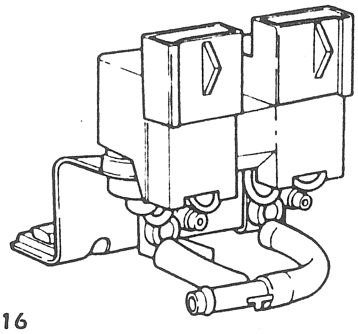


FIGURE 12-16
TAB and TAD solenoids. (Courtesy of Ford Motor Co.)

Upstream System Operation

Figure 12-19 illustrates system operation with Thermactor air directed to the upstream location. The system is in this phase of operation during engine warm-up; moderate acceleration, with less than a 60 percent throttle opening when the engine is not at operating temperature; and momentary engine deceleration.

During this phase of operation, the ECA grounds both the TAB and TAD solenoids. This action opens both the solenoid vacuum valves. As a result, manifold vacuum on the bypass and diverter diaphragms moves both their metering valves open.

The open bypass valve allows pump air to enter the passage to the diverter valve. The open diverter valve, in turn, channels the air to the upstream manifold location.

Downstream System Operation

Figure 12-20 shows the operation of the system with Thermactor air directed to the downstream location at the converter. The system is in this phase of operation during cruising speeds, when the engine is at normal operating temperature and at a light throttle setting; and during momentary engine deceleration at normal operating temperature.

The ECA under these conditions grounds the TAB solenoid but not the TAD unit. This action opens the TAB solenoid vacuum valve and closes the TAD vacuum valve.

The open TAB valve allows the engine vacuum to move the bypass diaphragm and metering valve to the up position. This allows pump air to pass into the channel to the diverter valve.

With no vacuum on the diverter valve, its spring moves its diaphragm valve to the left, closing the upstream port. Consequently, pump air passes out of the lower port and to the converter downstream location.

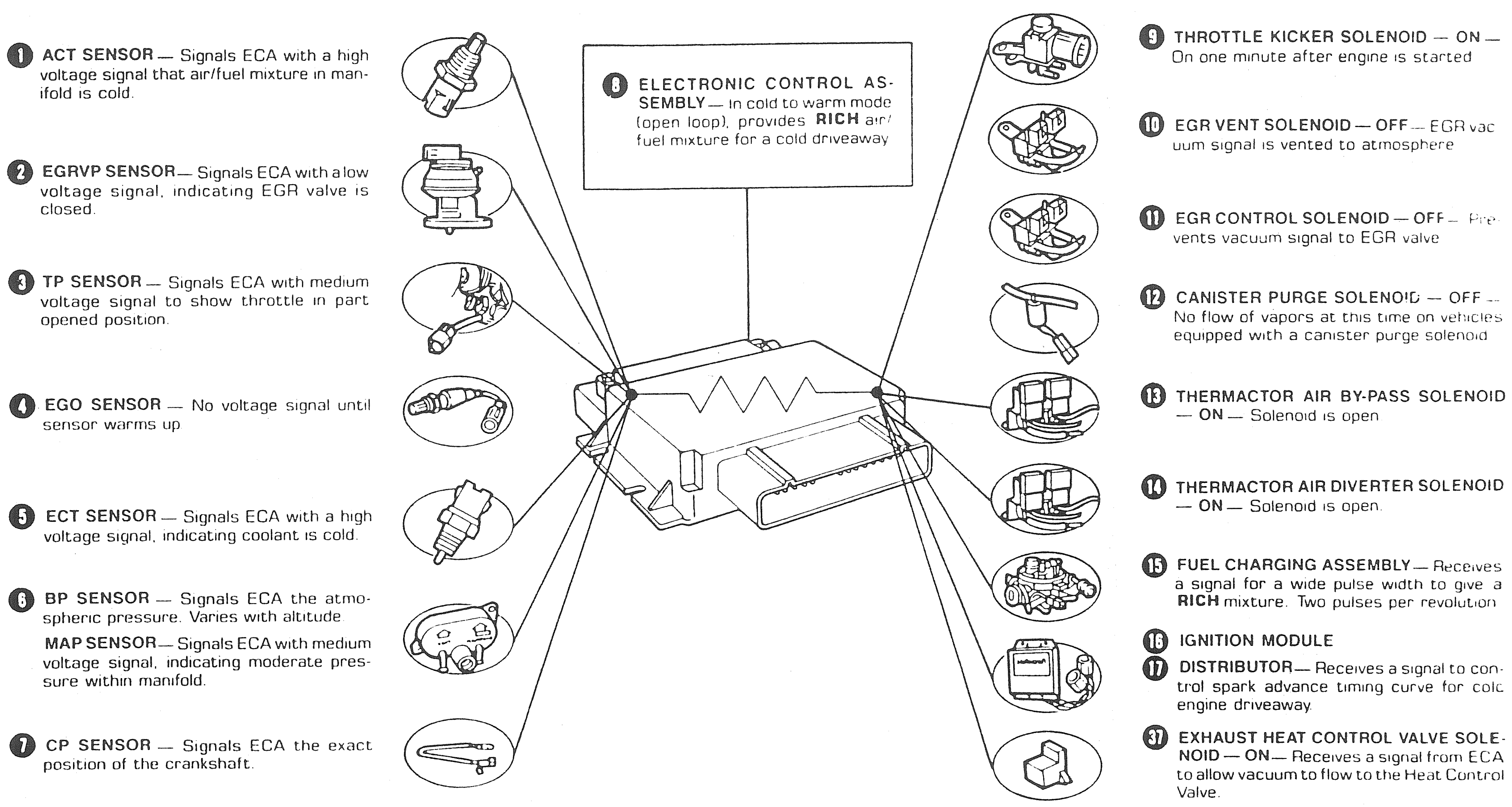


FIGURE 12-17
Electronic control assembly input and output signals. (Courtesy of Ford Motor Co.)

- Engine operation signals tell ECA that engine is cold or exhaust too rich

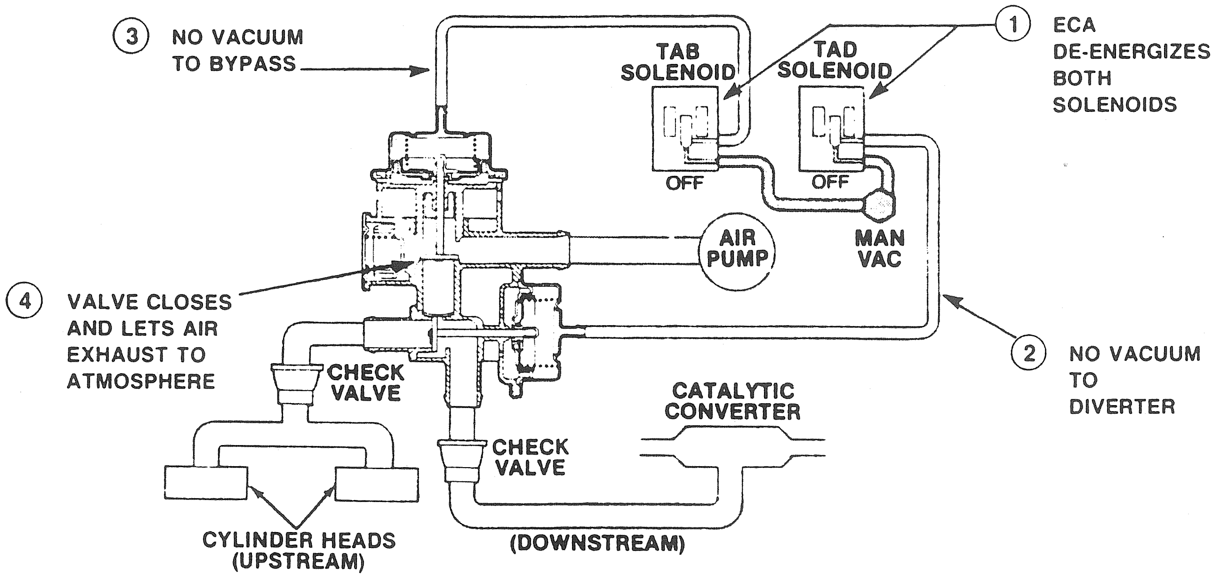


FIGURE 12-18
System operation with air bypassed to the atmosphere. (Courtesy of Ford Motor Co.)

- Engine mode calls for air to exhaust manifold (warmup or rich exhaust)

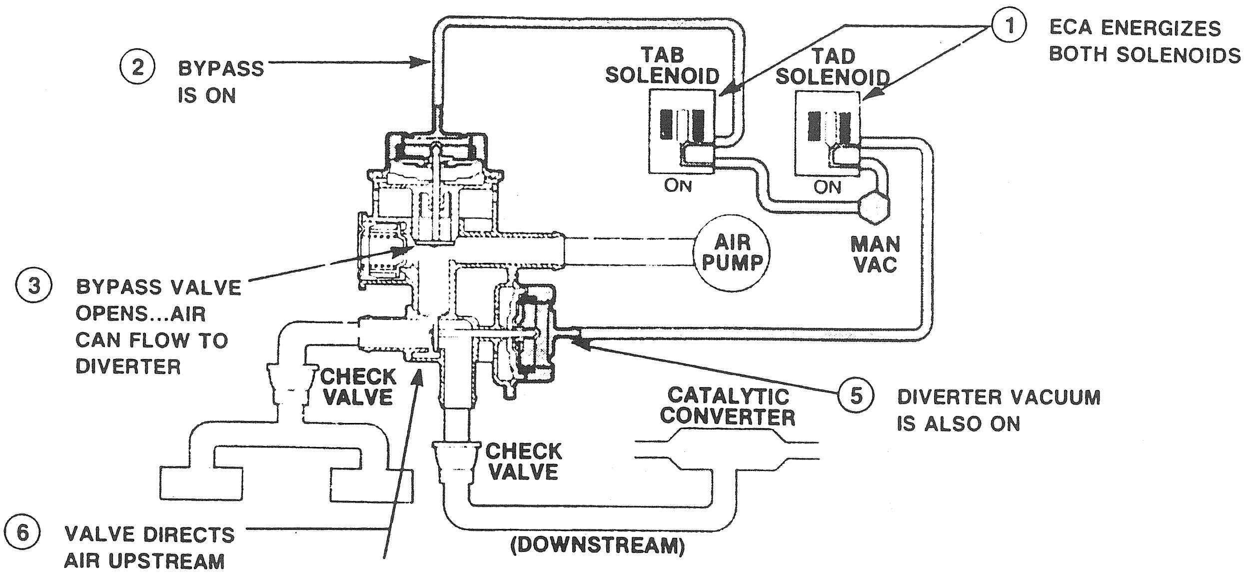


FIGURE 12-19
Upstream system operation. (Courtesy of Ford Motor Co.)

DOWNSTREAM OPERATION

- ECA senses warm engine cruise condition

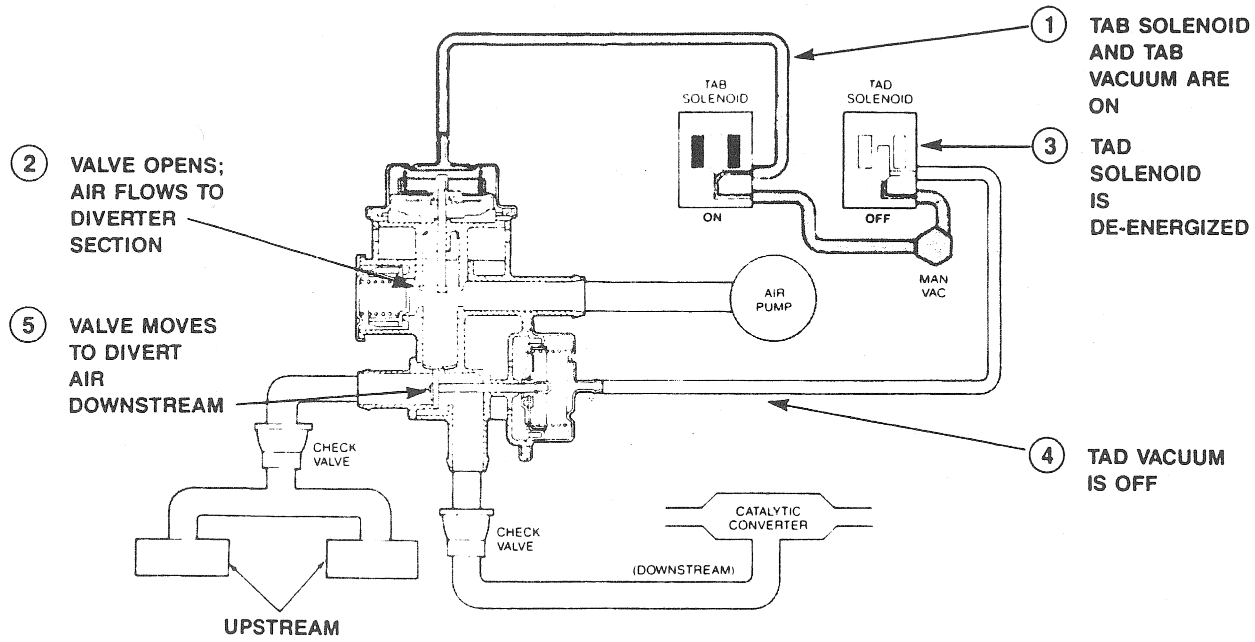


FIGURE 12-20
Downstream system operation. (Courtesy of Ford Motor Co.)

- Any operating mode except by-passing
- Depends on volume and pressure of air from pump

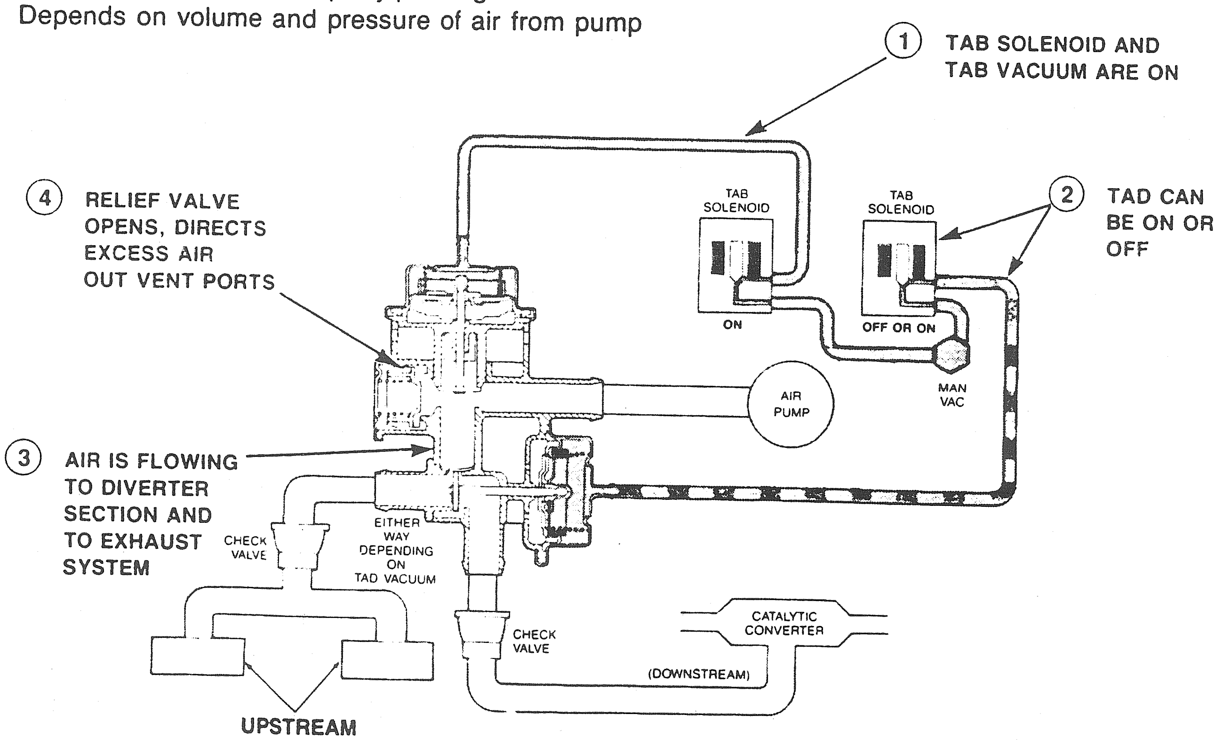


FIGURE 12-21
Relief valve operation. (Courtesy of Ford Motor Co.)

Relief Valve Operation

Figure 12-21 illustrates the operation of the relief valve during all operating modes except bypass. The relief valve opens depending on the volume and pressure of the air from the pump.

In this situation, the ECA grounds the TAB solenoid; however, it *may or may not* ground the TAD unit. With the TAB solenoid energized, its vacuum valve opens. This allows the engine vacuum to move the bypass diaphragm and valve to the up position. Pump air can now pass to the diverter valve.

Depending on whether the TAD solenoid is energized or not, pump air will then pass either to the upstream or downstream location. But in either case, if air pressure is too high, the relief valve will open and dump a portion of the pump air into the atmosphere. The spring closes the relief valve when air pressure drops to a pre-set value.

12-4 TYPICAL CHRYSLER COMPUTERIZED AIR INJECTION

The Chrysler air injection system used with dual-bed catalytic converters has the same function and is quite similar to the Ford system described in Section 12-3. The main difference between the two systems lies in Chrysler's design and operation of the switching and diverter valves, which take the place of Ford's combination valve (Fig. 12-22).

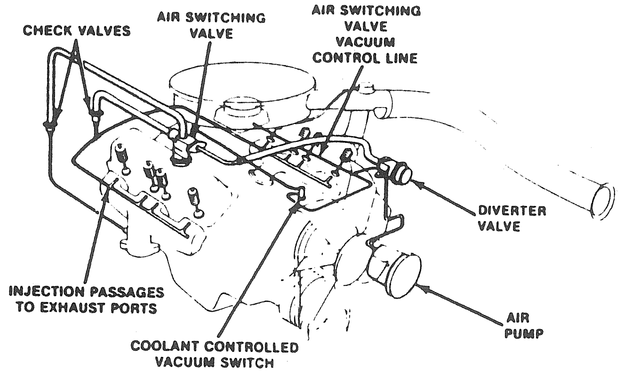


FIGURE 12-22
Air injection system. (Courtesy of Chrysler Motors Corp.)

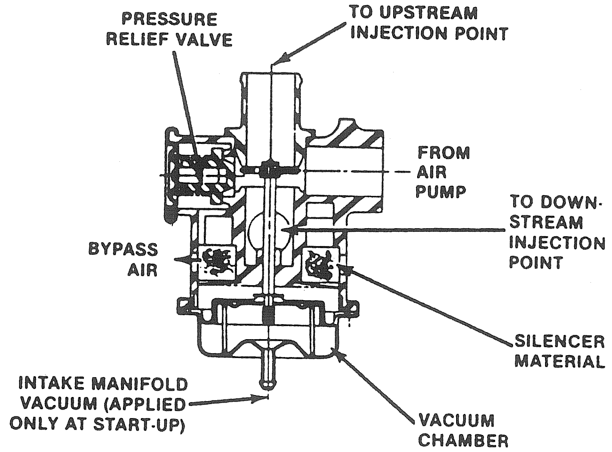


FIGURE 12-23
Design of the air switching and relief valves. (Courtesy of Chrysler Motors Corp.)

Diverter Valve

In the Chrysler system, the diverter valve is a single assembly that mounts and operates separately from the switching and relief valves. The diverter valve is in the line between the pump and the switching valve and functions during engine deceleration to dump pump air pressure to the atmosphere. This action prevents an exhaust backfire.

Combination Air Switching and Relief Valves

The *air switching and relief valves* are built into one assembly (Fig. 12-23). This assembly has several functions. For instance, the air switching valve routes pump air either to the upstream or downstream locations. The relief valve controls pump output pressure at high engine speeds.

This whole assembly consists of a vacuum diaphragm and dual-acting valve, three ports, a pressure relief valve, and silencer material. The diaphragm and spring are located in a sealed chamber at the lower side of the assembly that is shown in Fig. 12-23. The intake manifold vacuum is applied to the fitting of the chamber whenever the engine is operating at a less than normal operating temperature.

Attached to the diaphragm is the double-acting valve and stem. The valve is responsible for directing the air to either the upstream or downstream port opening of the assembly. If the engine vacuum acts on the diaphragm and valve, it will be in the down position. This allows pump air entering the right-hand port to pass out the upper port to the upstream point. If, on the other hand, the vacuum is cut off to the diaphragm, the spring pushes it and the valve up. This action closes off the upstream port and opens the downstream port in the center of the assembly.

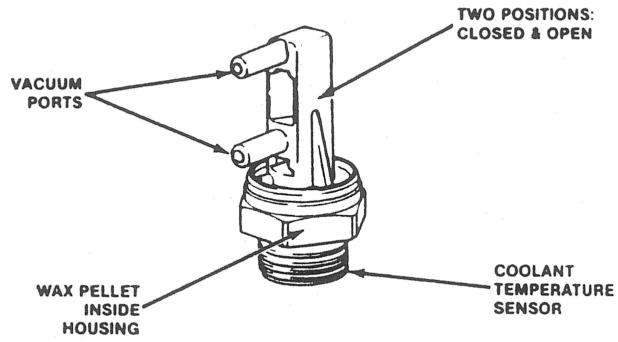


FIGURE 12-24
Coolant vacuum switch. (Courtesy of Chrysler Motors Corp.)

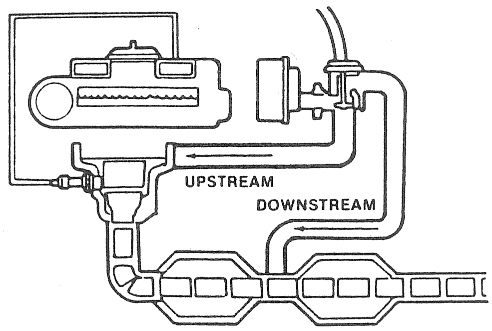


FIGURE 12-25
Control of air switching. (Courtesy of Chrysler Motors Corp.)

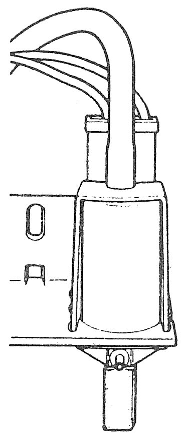


FIGURE 12-26
Air switching solenoid. (Courtesy of Chrysler Motors Corp.)

The relief valve has a calibrated spring. If pump pressure becomes too high, it overcomes spring tension and moves the relief valve open. Excessive pump pressure then vents to the atmosphere via the silencer material.

Coolant Vacuum Switch

On vehicles without computerized air injection systems, the operation of the air switching valve is under the control of a coolant vacuum switch (Fig. 12-24). The switch shown has two positions, closed and open, and operates by means of a wax pellet. The vacuum switch is known as a *coolant vacuum switch cold open (CVSCO)* because the unit permits a vacuum signal to pass through it when the engine is at less than operating temperature. The vacuum signal causes the switching valve to move downward and open the upstream port to pump air.

At operating temperature, the wax pellet closes the CVSCO switch, and it acts as a valve to close off the vacuum signal to the switching valve. The vacuum in the signal line to the switching valve bleeds off via an orifice. With the vacuum signal gone, the switching valve spring closes the valve to block the upstream port. With the downstream port now open, pump air moves into the catalytic converter (Fig. 12-25).

Electric Solenoid

On computerized air injection systems, vacuum control to the switching valve is accomplished by an *electric solenoid*, which is similar in design and operation to the Ford TAB and TAD solenoids (Fig. 12-26). The computer, responding to a below-specified temperature signal from the coolant sensor, completes the ground circuit to open the solenoid. This action opens the valve within the solenoid for the passage of the vacuum signal to the switching valve, which directs pump air to the upstream exhaust ports.

At a specified temperature, the computer breaks the solenoid ground circuit. This de-energizes the solenoid, and the vacuum signal is blocked to the switching valve. The switching valve now directs pump air to the downstream converter location.

12-5 TYPICAL GENERAL MOTORS COMPUTERIZED AIR INJECTION

The General Motors computerized air injection system is quite similar in design and has the same function as the Ford and Chrysler systems presented in Sections 12-3 and 12-4. The main difference lies in the large number of different control valves used by General Motors on its various engine and vehicle configurations. It would be impossible to cover all

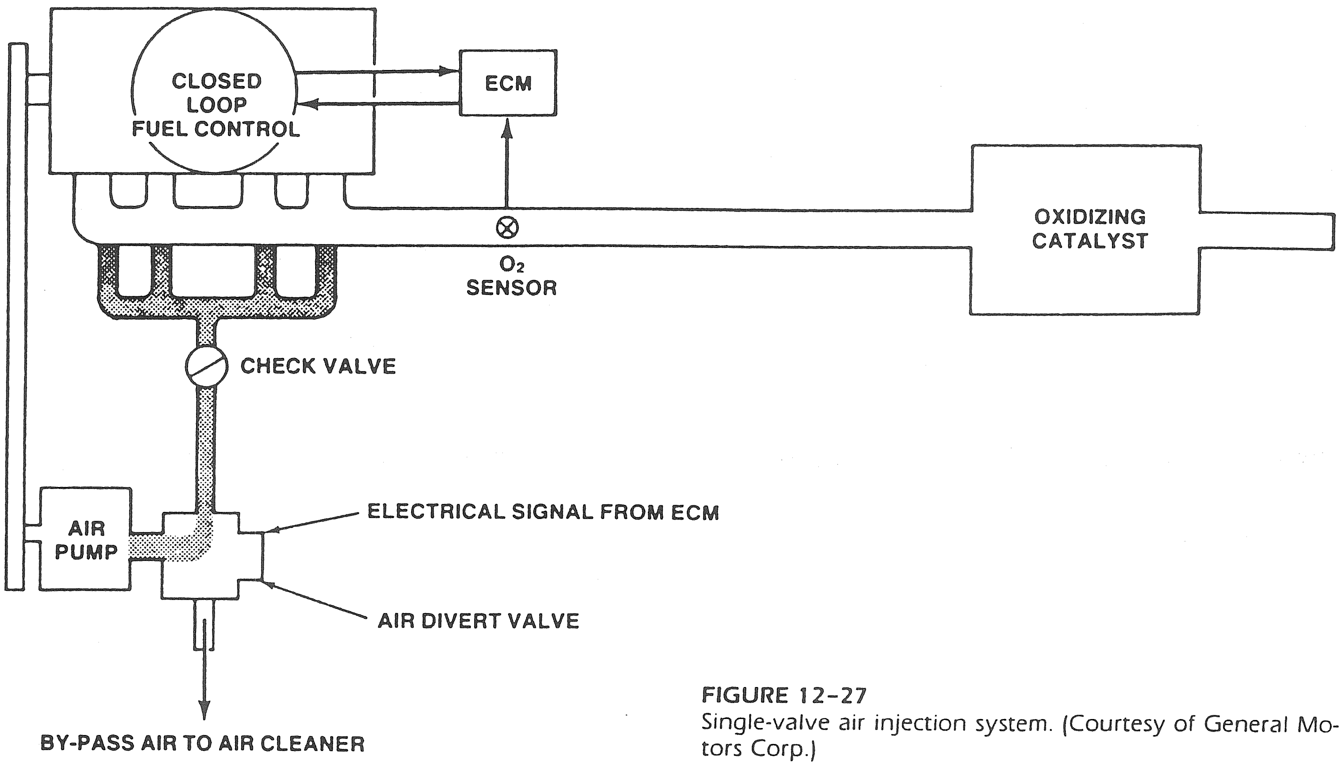


FIGURE 12-27
Single-valve air injection system. (Courtesy of General Motors Corp.)

the valves in current use. Therefore, this section will present the two basic General Motors systems and the typical control valving used in each one.

Single-Valve System

General Motors has used computer-controlled air injection on vehicles with only an oxidizing catalytic converter (Fig. 12-27). This system is known as a single-valve design because it utilizes only a diverter valve to control the flow of pump air.

In this system, there is no downstream location for pump air, so the diverter valve directs pump air to the exhaust ports during normal operation. The air reacts with the hot exhaust gases to begin the oxidation process of HC and CO compounds. The additional air is also used by the oxidation catalyst to complete the process.

During engine deceleration, the diverter valve directs pump air from the exhaust ports to the air cleaner. This prevents engine backfire, improves fuel economy, and protects the catalytic converter.

Electric Control Valve

The *electric control valve (EAC)* used in the single-valve system combines electronic control with the normal function of a diverter valve (Fig. 12-28). The

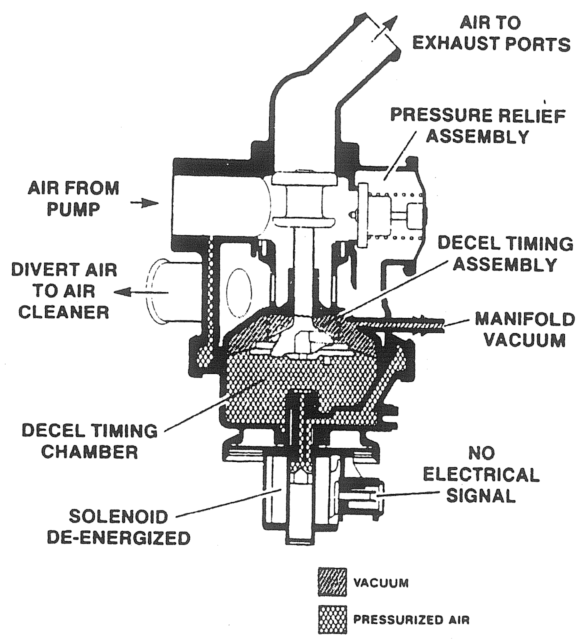


FIGURE 12-28
Electric control valve. (Courtesy of General Motors Corp.)

EAC bolts to the pump and consists of a pressure relief valve, diaphragm and double-acting valve, calibrated spring, vacuum tube and chamber, deceleration timing chamber, and electric solenoid. The spring-loaded relief valve controls system pressure by exhausting excess pump air to the air cleaner.

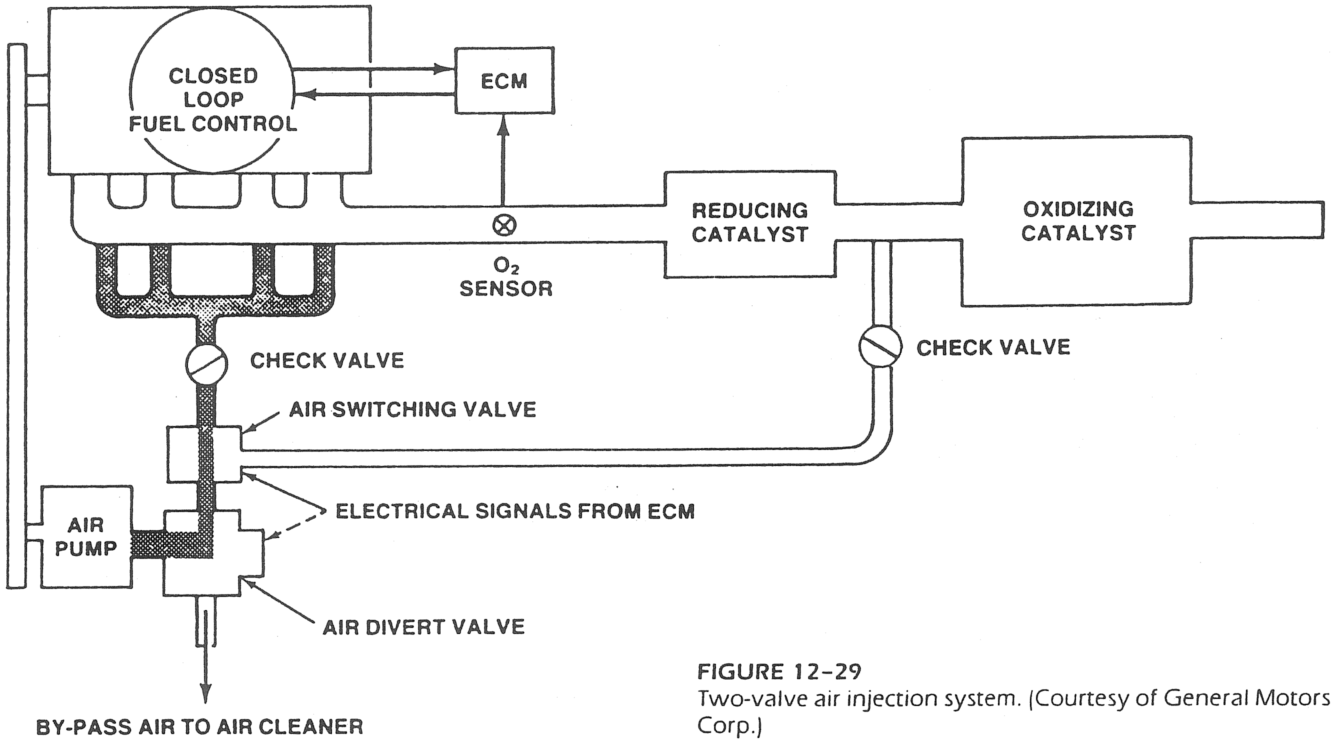


FIGURE 12-29
Two-valve air injection system. (Courtesy of General Motors Corp.)

The diaphragm and double-acting valve mount between two sealed chambers, the manifold vacuum, and deceleration timing chamber. The calibrated spring holds the diaphragm and double-acting valve in the down or normal operating position.

The vacuum chamber has a signal tube that connects via a hose to the intake manifold. Therefore, with the engine operating, the vacuum acts on the upper side of the diaphragm. Normally, the vacuum would move the diaphragm and the valve to the up or divert position, further compressing the calibrated spring. However, the normal vacuum signal is bled off through the *decel timing assembly,* located in the metering valve stem. Consequently, the spring maintains the valve in the down position during normal engine operation.

During engine deceleration, the *decel timing chamber* is pressurized by air from the pump. The air places sufficient pressure on the diaphragm to overcome spring tension. As a result, the diaphragm and valve move upward, closing off the air flow to the exhaust ports. In this situation, pump air now diverts to the air cleaner.

The *electric solenoid* controls the air flow from the pump to the decel chamber. When the ECM de-energizes the solenoid, pump air enters the chamber, causing the EAC to divert pump air to the air cleaner.

Any time the ECM energizes the solenoid, pump air is cut off from the decel chamber. The EAC can then act like a standard diverter valve and direct pump air to the exhaust ports.

Two-Valve System

Figure 12-29 is a schematic of a typical two-valve air injection system. Notice how similar this system is to the single-valve design just discussed. The main differences are that the two-valve system incorporates a dual-bed converter and an air switching valve. The air switching valve is necessary to direct pump air to the dual-bed converter when it is signaled to do so by the ECM. The system can utilize a number of different types of combination valves depending on engine and vehicle configurations.

Electric Divert/Electric Air Switching Valve

One of the typical combination valves used with this system is the *electric divert/electric air switching (EDES) valve* (Fig. 12-30). This combination valve consists of a diverter valve and solenoid, pressure relief valve, and air switching valve and solenoid.

During normal operation, the ECM energizes the diverter solenoid. The solenoid valve now opens to permit the engine vacuum to enter the lower vac-

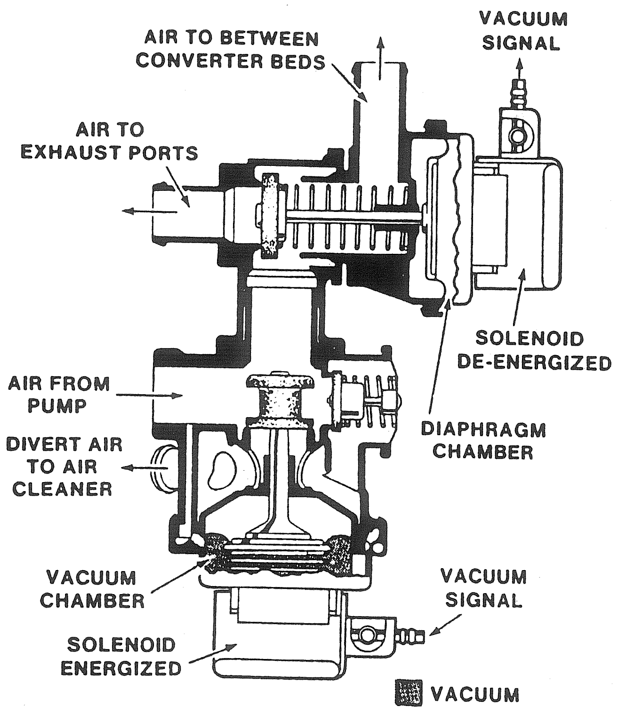


FIGURE 12-30
Electric divert/electric air switching (EDES) valve. (Courtesy of General Motors Corp.)

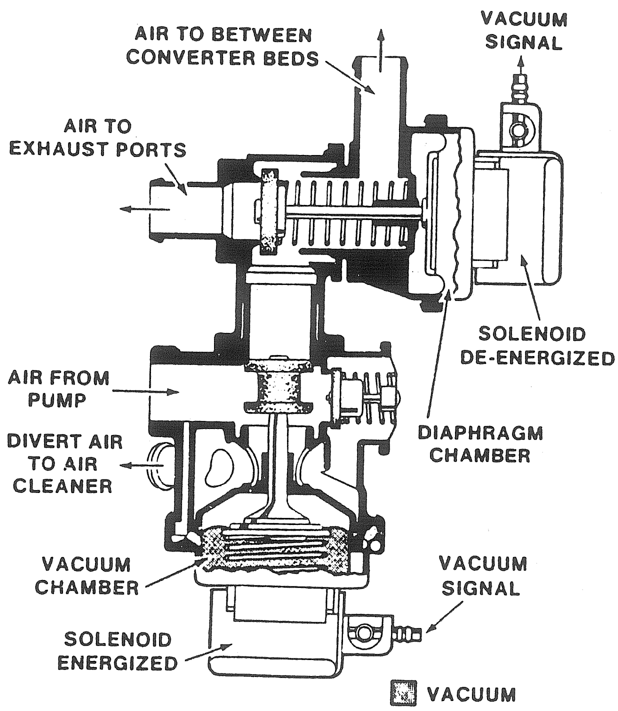


FIGURE 12-31
Air divert at wide-open throttle. (Courtesy of General Motors Corp.)

uum chamber and act on the bottom of the diverter diaphragm. The diaphragm moves down against spring tension and seats the lower portion of the diverter double-acting valve. At this time, pump air can pass through the channel to the air switching valve.

Whenever the ECM decides an air divert is necessary, it de-energizes the solenoid. The solenoid valve now prevents engine vacuum from acting on the lower chamber. Under this situation, spring tension pushes the diaphragm and its double-acting valve up, causing the air to divert to the air cleaner (see Fig. 12-30).

At wide-open throttle, there is not enough engine vacuum available to overcome spring tension. Consequently, the double-acting valve also moves to its up position, so air is diverted to the air cleaner (Fig. 12-31).

The upper portion of the combination valve contains the air switching assembly (Fig. 12-32). This assembly also consists of a spring-loaded diaphragm, double-acting valve, vacuum chamber, and solenoid.

When the ECM grounds the solenoid, it energizes and permits the engine vacuum to act on the chamber of the diaphragm. The vacuum on the diaphragm itself overcomes spring tension and the at-

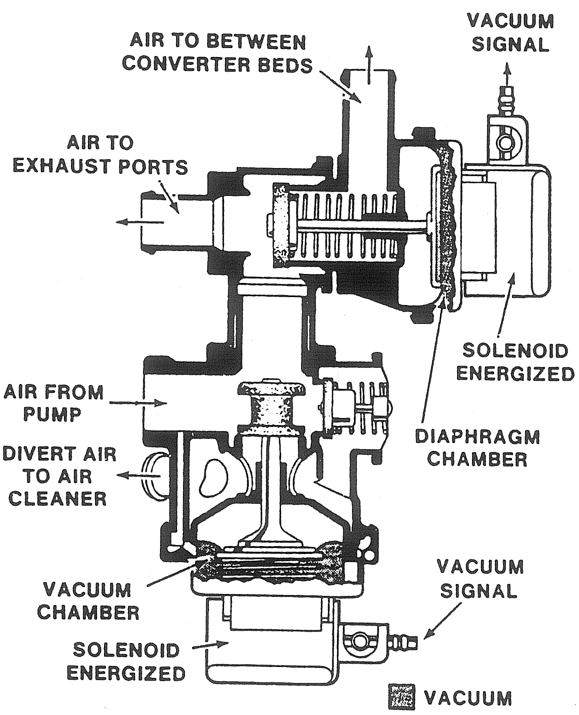
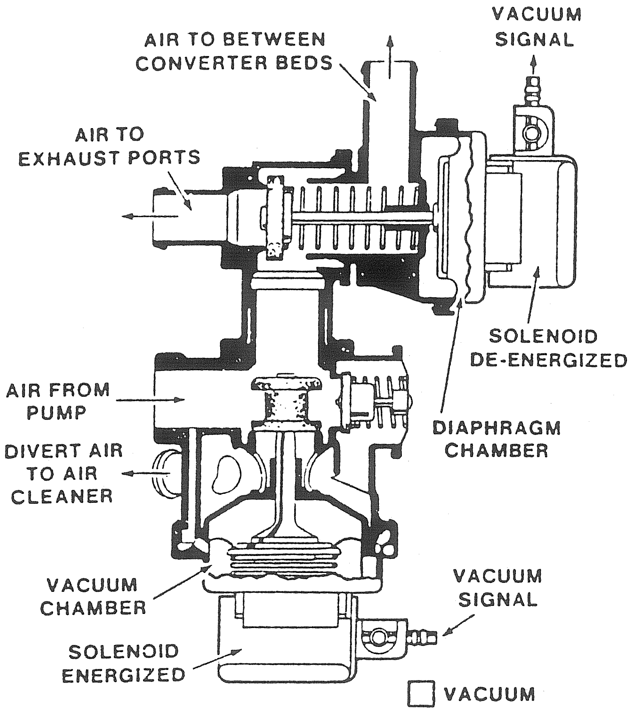


FIGURE 12-32
Air directed by switching valve to exhaust ports. (Courtesy of General Motors Corp.)



tached valve moves to the position shown in Fig. 12–32. Pump air can now flow to the exhaust ports to increase oxidation of HC and CO compounds.

If the ECM breaks the ground to the solenoid, it de-energizes. As a result, engine vacuum is cut off to the diaphragm chamber, and the vacuum vents to the atmosphere (Fig. 12–33). The spring moves the diaphragm and its attached valve to the position shown, and pump air flows between the converter beds. The air aids the rear-bed oxidizing catalyst in decreasing the HC and CO levels within the exhaust gases.

FIGURE 12–33
Air directed by switching valve to converter. (Courtesy of General Motors Corp.)

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. Which General Motors computerized system only requires a diverter and pressure relief valve [12-5]?

2. Describe the function of an air injection system [12-1].

3. What is the basic design difference between the Fort MTA and the Chrysler system [12-4]?

4. Name the components of a basic air injection system [12-2].

5. Which portion of the dual-bed converter has a catalyst that reduces NO_x levels [12-3]?

REVIEW

1. Why is air diverted to the air cleaner during hard acceleration of a General Motors engine [12-5]?
   a. due to a loss of the ECM signal
   b. due to a reduction in engine vacuum
   c. because the pump relief valve opens
   d. because the one-way check valve closes

2. When does the rear bed of the converter receive injection air [12-1]?
   a. when the engine is cold and idling
   b. when the engine is at normal temperature
   c. when the engine is cold and accelerating
   d. both a and c

3. Where are the diverter and air switching solenoids located in the General Motors system [12-5]?
   a. They are integral with the valve assembly.
   b. They are a separate assembly that is mounted on the fender panel.
   c. One is in a separate assembly, and the other is the integral type.
   d. none of these

4. Which emission level is low when the engine is cold [12-1]?
   a. HC
   b. CO
   c. NO_x
   d. both a and b

5. How does the Chrysler computer energize the air injection solenoid [12-4]?
   a. by providing a ground circuit
   b. by directing a voltage signal to it
   c. by directing air pressure to it
   d. by cutting off air pressure to it

6. How is injection air filtered [12-2]?
   a. through the pump centrifugal fan
   b. by means of an internal filter
   c. by means of the air cleaner
   d. none of these

7. Which sensor signals does Ford's ECA use to determine when to energize the TAB and TAD solenoids [12-3]?
   a. ECT sensor
   b. TP sensor
   c. both a and b
   d. neither a nor b

8. What prevents exhaust gases from backing up into the air pump [12-2]?
   a. nozzles
   b. diverter valve
   c. relief valve
   d. check valve

9. On a computerized Chrysler injection system, what controls the vacuum to the air switching valve [12-4]?
   a. electric solenoid
   b. coolant vacuum valve
   c. delay timer
   d. both a and c

10. Which device in the air injection system prevents an exhaust backfire [12–2]?
   a. check valve
   b. diverter valve
   c. relief valve
   d. none of these

11. In the MTA system, which valve directs the air into the atmosphere during deceleration [12–3]?
   a. diverter
   b. bypass
   c. relief
   d. one-way check

12. In the Ford MTA system, the air control valve is found where [12-3]?
   a. in the combination valve
   b. in the diverter valve
   c. in the relief valve
   d. in the pump

Chapter 13

TESTING A TYPICAL AIR INJECTION SYSTEM

OBJECTIVES

After reading and studying this chapter, you should be able to

- check and adjust an air pump drive belt.
- test air pump output.
- check the operation of a typical standard diverter valve.
- test an air check valve.
- check a combination valve for serviceability.
- inspect air manifolds and tubes for serviceability.
- test an electric solenoid.
- check a typical solenoid electrical circuit.
- test an exhaust system for excessive back pressure.

As mentioned in the last chapter, air injection is an add-on system used to lower HC, CO, and, in newer systems, NO_x emissions. Moreover, air injection does not affect the operation of the ignition system or, under normal conditions, the air/fuel ratio. However, as will be shown later, a vacuum leak in a system component can affect the normal air/fuel ratio. Therefore, failure to deliver injection air to the exhaust manifold or catalytic converter will not affect engine performance. It will, of course, decrease the oxidation of HC and CO compounds and reduce the conversion of NO_x. This will cause a vehicle to fail the tailpipe emissions test.

It should be obvious that in order for the system to perform its functions, it does require some service and periodic testing. The type and frequency of this preventive maintenance vary somewhat among vehicle manufacturers and system designs. Therefore, you will have to use factory instructions and specifications when checking out a particular system due to possible alterations within the basic system. These changes are necessary in order for the manufacturer to install the system on different engine and vehicle configurations. The following sections present some of the most common test procedures used on typical systems.

13-1 CHECKING THE DRIVE BELT AND AIR PUMP OPERATION

If a vehicle does not pass the tailpipe emissions test, check the serviceability of the system by first checking the condition of the air pump drive belt. Inspect the belt for wear, cracks, or deterioration. Replace the belt if it is defective.

Belt Tension Adjustment

If the belt is in satisfactory condition, check its tension by doing the following:

1. Run the engine until it reaches normal operating temperature.

2. Install a belt tension gauge (Fig. 13-1).

3. With the gauge, check belt tension against specifications.

4. If the tension is off, check the torque on the crank pulley mounting bolts. Tighten the bolts as necessary.

5. Loosen the air pump mounting and adjusting arm bolts.

6. Install the belt tension tool, and adjust it until belt tension is to specifiations.

Caution: Do not use a pry bar against the pump housing to adjust belt tension. The pump housing will be dented or creased, which will result in a noisy or seized pump.

7. Tighten the air pump mounting and adjusting arm bolts.

8. Recheck belt tension. If it is now correct, remove the gauge and belt tension tool.

9. If belt condition and tension are correct, check the air pump for excessive noise when operating.

Checking the Pump for Excessive Noise

The air pump rarely causes any problems except noise. Just keep in mind that the air injection system, by its nature, is never completely free of noise. However, excessive pump noise can indicate a unit failure.

In a positive displacement pump, the noise raises in pitch with increases in engine speed. But a new pump may become less noisy after a break-in mileage of about 500 miles. If the noise persists after the break-in period or the noise is excessive, replacement of the pump may be necessary. Other causes of noise at the pump are a loose pulley, loose mounting, incorrectly adjusted or aligned drive belt, or a kinked or restricted hose. Figure 13-2 illustrates a step-by-step troubleshooting guide for locating the cause of excessive pump noise.

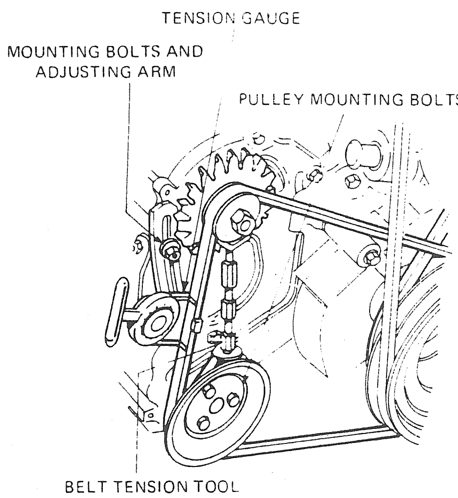


FIGURE 13-1
Typical belt adjustment.

AIR PUMP NOISE DIAGNOSIS

- Do not service unless pump has run 500 miles

CONDITION	POSSIBLE SOURCE	ACTION
Excessive Belt Noise	• Loose belt	• Tighten to specification using Tool T75L-9480-A or equivalent to hold belt tension and Belt Tension Gauge T63L-8620-A or equivalent. **CAUTION: Do not use a pry bar to move air pump.**
	• Seized pump	• Replace pump.
	• Loose pulley	• Replace pulley and/or pump if damaged. Tighten bolts to 13.6-17.0 N•m (120-150 lb-in).
	• Loose or broken mounting brackets or bolts	• Replace parts as required and tighten bolts to specification.
• Excessive Mechanical Clicking	• Overtightened mounting bolt	• Tighten to 34 N•m (25 lb-ft).
	• Overtightened drive belt	• Same as loose belt.
	• Excessive flash on the air pump adjusting arm boss	• Remove flash from the boss.
	• Distorted adjusting arm	• Replace adjusting arm.
• Excessive Thermactor System Noise (Putt-Putt, Whirling or Hissing)	• Leak in hose	• Locate source of leak using soap solution, and replace hoses as necessary.
	• Loose, pinched or kinked hose	• Reassemble, straighten, or replace hose and clamps as required.
	• Hose touching other engine parts	• Adjust hose to prevent contact with other engine parts.
	• Bypass valve inoperative	• Test the valve.
	• Check valve inoperative	• Test the valve.
	• Pump or pulley mounting fasteners loose	• Tighten fasteners to specification.
	• Restricted or bent pump outlet fitting	• Inspect fitting, and remove any flash blocking the air passage way. Replace bent fittings.
	• Air dumping through bypass valve (at idle only)	• On many vehicles, the thermactor system has been designed to dump air at idle to prevent overheating the catalyst. This condition is normal. Determine that the noise persists at higher speeds before proceeding.
	• Air dump through bypass valve (decel and idle dump)	• On many vehicles, the thermactor air is dumped in air cleaner or in remote silencer. Make sure hoses are connected and not cracked.
• Excessive Pump Noise (Chirps, Squeaks and Ticks)	• Loose pulley or mounting bolts or worn or damaged pump	• Check the thermactor system for wear, loose pulley mounting bolts, or damage and make necessary corrections.

FIGURE 13-2
Air pump noise diagnosis. (Courtesy of Ford Motor Co.)

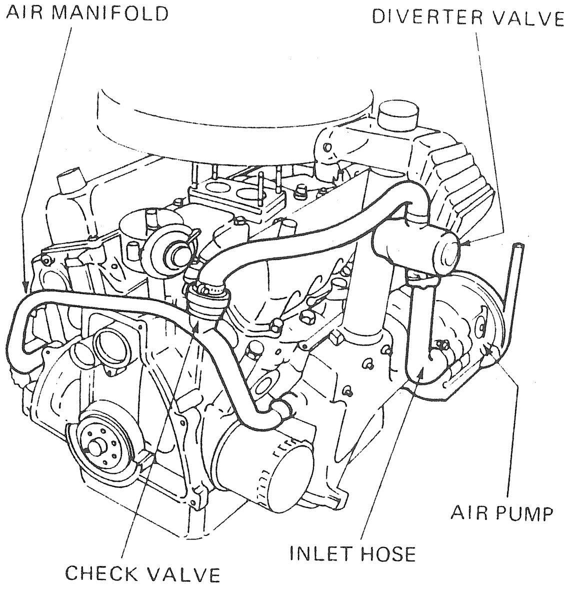


FIGURE 13-3
Diverter valve inlet hose.

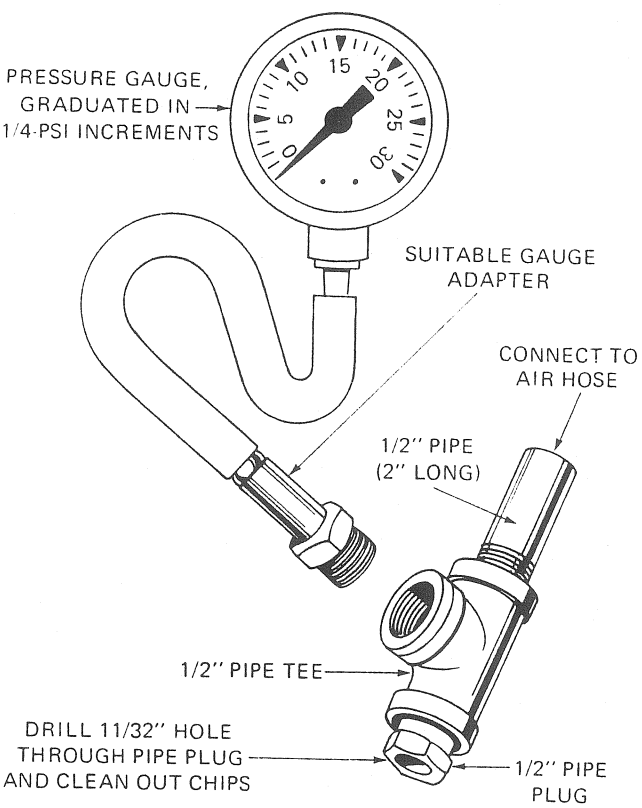


FIGURE 13-4
Pressure gauge and adapter tool.

Testing Pump Operation

If the pump itself is not noisy, check its operation by doing the following:

1. Inspect all hoses and their connections. Repair or replace defective hoses or connections.
2. Make sure belt tension is to specifications.
3. Run the engine until it reaches normal operating temperature.
4. Shut the engine off.
5. If the diverter valve is bolted to the pump, remove its outlet hose. On externally mounted diverter valves, disconnect its inlet hose (Fig. 13-3).
6. Install the pressure gauge to the hose with the adapter and fabricated tool shown in Fig. 13-4.

Caution: Clamp the tool tightly in place over the hose to prevent it from being blown off by pump pressure. Also, position the tool so that the output air through the drilled hole will be directed away from you.

7. Following the manufacturer's instructions, install a tachometer on the engine.
8. Start the engine and operate it at 1,000 rpm.
9. Note the pressure on the gauge. If the pressure is one psi or more, the pump is operating okay.
10. If the pressure is less than one psi or unsteady, replace the pump.
11. Remove the test gauge and adapter tool, and reinstall the removed inlet or outlet hose.
12. If the pump checked out satisfactorily, test the diverter valve.
13. Remove the tachometer from the engine.

13-2 TESTING A TYPICAL DIVERTER VALVE

A faulty diverter valve or loss of signal vacuum can cause an engine backfire. A diverter internal failure or leaking vacuum signal hose can also cause poor engine idle due to a leaning out of the air/fuel mixture. This condition is known as a *lean misfire.* To check diverter valve operation, do the following:

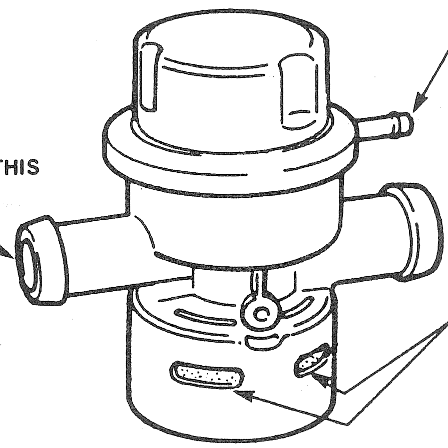


FIGURE 13-5
Testing a diverter valve. (Courtesy of Ford Motor Co.)

1. Check the condition of all hoses. A leaking vacuum line or loose hose will cause the valve to malfunction.

2. Disconnect the vacuum hose from the fitting on the valve (Fig. 13-5).

3. Start the engine, and place your finger over the end of the disconnected vacuum hose. If there is no suction, the hose or line is plugged. Replace the hose or otherwise clear the line.

4. Disconnect the outlet hose from the diverter valve.

5. With the engine running, air should come out of the diverter valve port (see Fig. 13-5).

6. With a vacuum pump, quickly apply 18 inches to 20 inches of vacuum to the signal hose fitting on the diverter valve. Pump air should momentarily discharge from the lower silencing port openings.

7. If no air is discharged from the lower ports, the valve is defective and requires replacement.

13-3 TESTING A TYPICAL COMBINATION VALVE

If a combination bypass, diverter, and pressure relief valve malfunctions, it can cause a loss of pump air to the exhaust ports or catalytic converter. A defective combination valve can direct pump air into the exhaust when the air/fuel ratio is too rich, such as during deceleration. This often causes a backfire and may melt the catalyst substrate. To check a typical combination valve for serviceability, do the following:

1. Run the engine until it reaches normal operating temperature, and then shut off the engine.

2. Mark and disconnect both vacuum signal hoses from the combination valve, and plug both hoses.

3. Disconnect the hoses from ports A and B of the valve (Fig. 13-6). Leave the pump inlet hose attached to the valve.

4. Following the manufacturer's instructions, install a tachometer onto the engine.

5. Start the engine and adjust the idle speed to 1,500 rpm.

6. With a vacuum pump, apply and then release 16 inches to 18 inches of vacuum to the upper bypass hose fitting.

7. With the vacuum applied, pump air must pass out of port B.

8. With the vacuum released, pump air must come out of the silencing dump ports.

9. If the bypass valve did not function as described, replace the combination valve.

10. Again apply 16 inches to 18 inches of vacuum to the upper bypass vacuum hose fitting and trap it.

11. Apply and then release 16 inches to 18

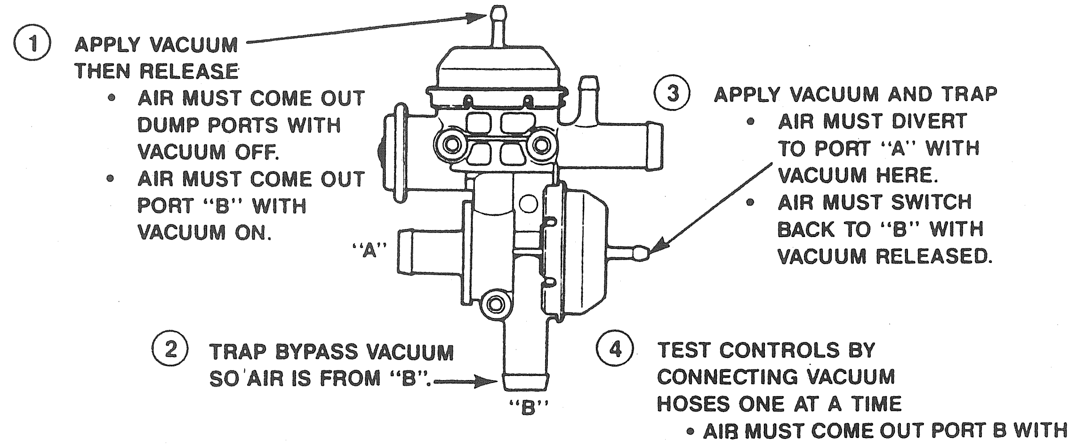


FIGURE 13-6
Checking a combination valve. (Courtesy of Ford Motor Co.)

inches of vacuum to the lower diverter valve vacuum fitting.

12. With vacuum applied, pump air must divert to Port A.

13. With vacuum released, pump air must come out of Port B.

14. If the diverter valve did not switch the air from Port A to Port B, replace the combination valve.

15. If the valve functioned satisfactorily, reinstall both vacuum signal hoses, one at a time.

16. With the bypass vacuum hose installed, air must come out of Port B.

17. With the diverter signal vacuum hose installed and the engine operating at 3,000 rpm, air should divert to Port B.

18. If the air did not switch, as outlined in Steps 16 and 17, check the vacuum solenoids by following the instructions given in this chapter or in the appropriate electronic control module circuit guide.

19. Shut the engine off and reconnect the outlet hoses to the combination valve.

20. Disconnect and remove the tachometer.

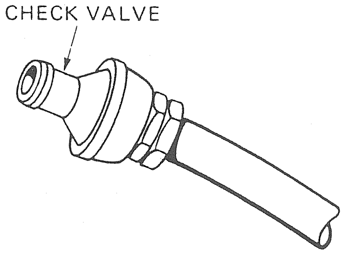


FIGURE 13-7
Testing a check valve.

13-4 TESTING THE CHECK VALVE AND AIR MANIFOLD

If the diverter or combination valves function okay, a check valve could be frozen closed, not allowing pump air to enter the manifolds. This, of course, prevents the injected air from performing its function of oxidizing the HC and CO compounds. Also, a closed valve can cause back-pressure loss that can affect the operation of the exhaust gas recirculation (EGR) system.

If a check valve is seized in the open position, the air pump can be damaged or the hoses will char or deteriorate rapidly. To test a check valve for either problem, do the following:

1. Disconnect the hose from the check valve (Fig. 13-7).

2. Blow through the valve toward the air manifold. Air should pass through the valve easily. If not, the valve is stuck closed and must be replaced.

3. Attempt to suck air back through the valve. You should not be able to. If you can, the valve is stuck open and requires replacement.

4. Reconnect the hose to the check valve.

Hoses and Air Manifolds

To check for serviceability of the hoses and air manifolds, do the following:

1. Inspect all hoses for holes or deterioration.

2. Check the air manifolds for holes or cracks.

3. Inspect all hose and manifold connections for tightness.

4. Check the routing of all the hoses. Any interference between the hoses and any other object may cause wear and an eventual leak.

5. If you suspect an air leak, check the involved areas with a soap and water solution. With the air pump operating, bubbles form at any area where a leak exists.

Caution: Be careful to keep the soapy water solution away from the centrifugal filter of the pump.

6. If an air manifold or hose is found defective, replace it.

Note: Manufacturers form air hoses of special materials that are resistant to high temperatures. Therefore, if a hose requires replacement, use only the proper hose type.

Air Injection Tubes

There is usually no periodic inspection or service for the air injection tubes. However, when it becomes necessary to remove the cylinder head or exhaust manifold from an engine, inspect the tubes for carbon build-up and for warpage or burned holes.

To service the exposed tubes, use a wire brush to remove any carbon build-up. If any of the tubes are warped or burned out, replace them or the complete air manifold assembly, if necessary.

13-5 TESTING AN ELECTRIC SOLENOID AND ITS CIRCUIT

On a computerized system, the electric solenoids control the vacuum supply to the combination valve. If the system does not function properly and the combination valve and the other components

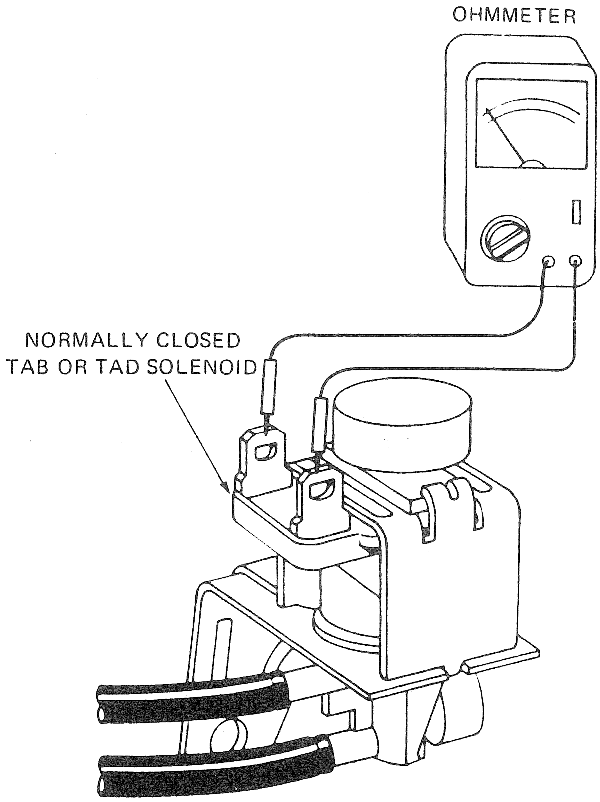


FIGURE 13-8
Resistance testing TAB and TAD solenoids.

checked out okay, follow this procedure to test both the solenoids and their operating circuits.

Solenoid Test

To check the resistance of a Ford TAB or TAD solenoid, do the following:

1. Turn the ignition switch off and wait ten seconds.

2. Unplug the TAB and TAD solenoid terminal connectors.

3. Set the ohmmeter scale for a R × 10 reading.

4. Touch an ohmmeter lead to each of the solenoid terminals (Fig. 13-8).

5. Note the reading on the ohmmeter. The resistance should be between 50 ohms and 100 ohms.

6. If the resistance on both solenoids is okay, proceed with the solenoid power check.

7. If the resistance is not to specifications, re-

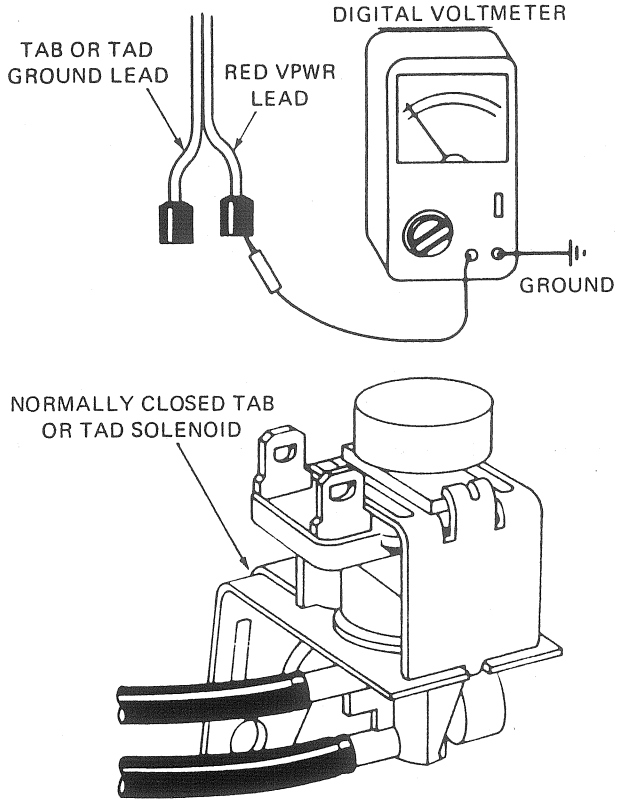


FIGURE 13-9
Testing for power to the TAB and TAD solenoids.

place the defective solenoid and plug in all connectors.

Solenoid Power Check

To test the availability of power to the TAB and TAD solenoids, do the following:

1. Turn the ignition switch off and wait ten seconds.

2. Unplug the TAB and TAD solenoid terminal connectors.

3. Turn the ignition switch to the RUN position.

4. Connect the (−) voltmeter lead to a good ground (Fig. 13-9).

5. Touch the (+) voltmeter lead to the red V PWR lead terminal for both solenoids.

6. Note the readings on the voltmeter.

7. Each reading should be 10.6 volts or greater.

8. If the reading is not to specifications, check the harness connectors. If they are okay, use the pinpoint tests within the appropriate service manual to locate the cause of the low voltage reading.

9. Turn the ignition switch off and plug in the solenoid connectors.

13-6 TESTING AN AIR INJECTION SYSTEM FOR EXCESSIVE BACK PRESSURE

A catalytic converter can become restricted at high vehicle mileage. Also, if leaded fuel is used, the converter can be *lead poisoned,* or if air is injected into a rich mixture, it can simply melt from excessive heat. In either case, the restricted converter causes very high back pressure, interferes with engine breathing, and generally makes the engine operate poorly. Finally, exhaust gas recirculation (EGR) flow will be affected on back-pressure systems.

There are two methods to check for a restricted converter. The first uses a vacuum gauge, and the second uses a pressure gauge.

Vacuum Gauge Test

This test can be performed on any type of engine, but it is the only way to test for excessive back pressure on engines without an air pump system. To perform the vacuum gauge test, do the following:

1. Inspect the entire exhaust system visually. Watch for collapsed components. Replace any damaged part.

2. Attach a vacuum gauge into any intake manifold fitting. Do not use a ported vacuum for this test.

3. Following the manufacturer's instructions, connect a tachometer to the engine.

4. Run the engine until it reaches normal operating temperature.

5. Run the engine at 2,000 rpm in neutral.

6. Check the reading on the vacuum gauge. It should read 16 or more inches of vacuum. If it does, the exhaust system is okay.

7. If the vacuum is low, remove the exhaust pipes from the manifolds. Repeat the vacuum test. If the vacuum is now okay, there is a restriction in

the exhaust system. In this case, go to Step 10.

8. If the vacuum is not okay, the exhaust manifolds may be the problem. Proceed to Step 9.

9. To check the exhaust manifolds, remove them from the engine. Drop a length of chain into each manifold port. If the chain does not pass through a port, remove the obstruction or replace the manifold.

10. To check for a restricted converter, reconnect the exhaust pipes, and then disconnect the muffler. Repeat the vacuum test.

11. If the vacuum is not okay, replace the catalytic converter. Also, inspect the muffler to be sure it has not collected any debris from the catalyst.

12. Reconnect any removed exhaust system components.

13. Remove the tachometer and vaccum gauge from the engine.

Pressure Gauge Test

This procedure can be used in place of the vacuum test on any engine with an air pump system. To perform this check, do the following:

1. Following the manufacturer's instructions, connect a tachometer to the engine.

2. Disconnect the outlet hose from the check valve (Fig. 13-10).

3. Adapt an air pressure gauge to the air manifold inlet tube. A propane-enrichment tool hose can be used for this purpose. Tape and seal the adapter hose as necessary.

4. Run the engine at 2,000 rpm in neutral.

5. Read the pressure on the gauge. The reading should not exceed 2-½ psi.

6. If the pressure is too high, check the exhaust system parts for restrictions, as outlined under the vacuum test. Replace any restricted muffler, converter, or manifold.

7. Remove the tachometer and pressure gauge.

8. Reinstall the check valve hose.

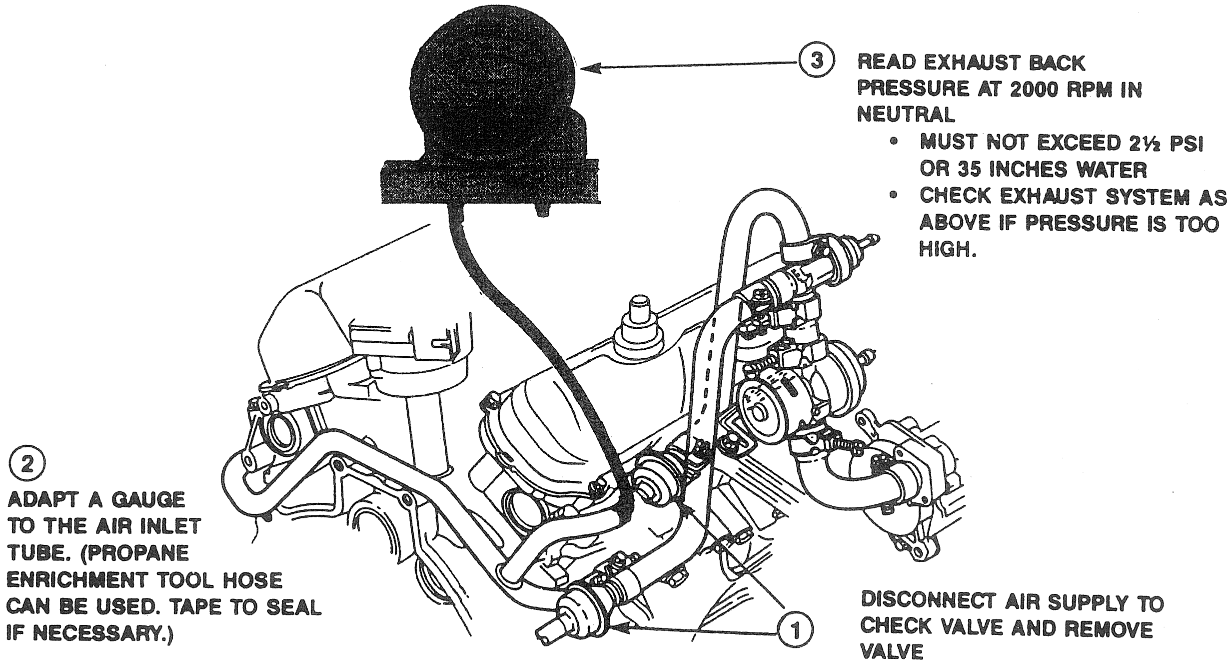


FIGURE 13-10
Testing an exhaust system for excessive back pressure. (Courtesy of Ford Motor Co.)

Chapter Review

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. Describe the effects of excessive back pressure [13-6].
2. What is the first item to check if the air injection system does not function [13-1]?
3. Which solenoid terminal lead has power to it with the ignition switch on [13-5]?
4. What are the symptoms of a faulty diverter valve [13-2]?
5. What types of problems can a faulty check valve cause [13-4]?
6. What effect will a defective combination valve have on a catalytic converter [13-3]?

REVIEW

1. What is the symptom of excessive back pressure [13-6]?
   Technician A states a vacuum gauge reading of less than 16 inches at 2,000 rpm.
   Technician B says a pressure gauge reading of more than 2-½ psi at 2,000 rpm.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
2. During a pump test, how much air pressure should the pump produce [13-1]?
   Technician A says 5 psi.
   Technician B replies 10 psi.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
3. What is a satisfactory resistance reading for a TAB solenoid [13-5]?
   a. 10 ohms to 20 ohms
   b. 20 ohms to 40 ohms
   c. 40 ohms to 80 ohms
   d. 50 ohms to 100 ohms
4. How will a diverter valve perform if it loses its manifold vacuum signal [13-2]?
   a. Pump air will come out the diverter and silencer ports.
   b. Pump air will come out the diverter port.
   c. both a and b
   d. neither a nor b
5. What do you use to check for injection manifold or hose air leaks [13-4]?
   Technician A states solvent.
   Technician B replies a soap and water solution.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
6. To test a combination valve, where should pump air come out when you apply a vacuum to the bypass fitting [13-3]?
   Technician A says the downstream Port B.
   Technician B states the upstream Port A.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b

Chapter 14

COMPUTERIZED EGR SYSTEMS

OBJECTIVES

After reading and studying this chapter you will be able to

- explain the function and design of a basic exhaust gas recirculation (EGR) system.
- describe the design and operation of a typical Ford computerized EGR system.
- explain the design features and operation of a typical Chrysler computerized EGR system.
- describe the design and operation of a typical General Motors EGR system.

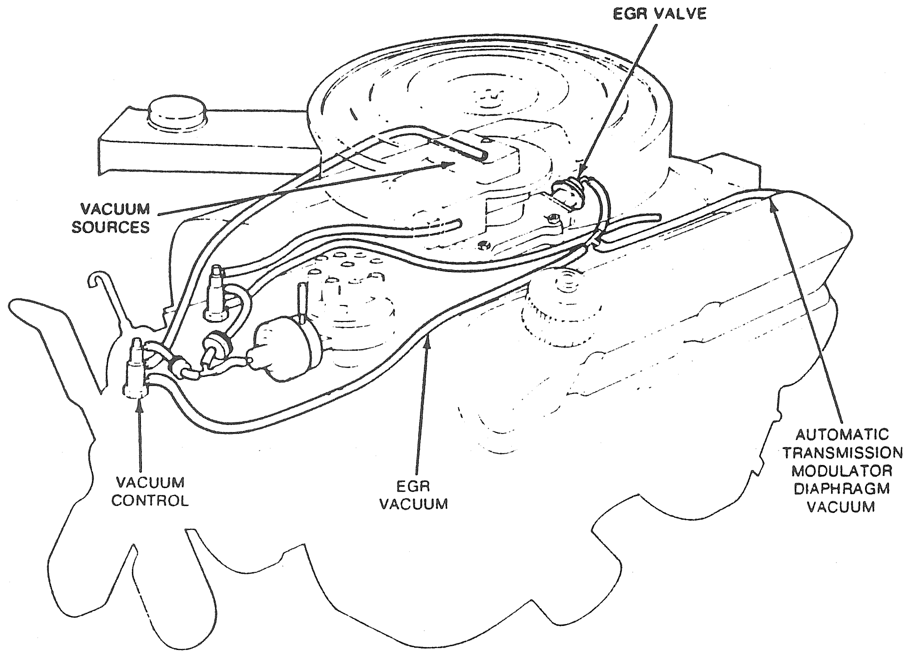


FIGURE 14-1
EGR systems reduce combustion chamber temperatures and thus reduce the formation of No_x (Courtesy of Ford Motor Co.)

As mentioned in Chapter 12, a dual-bed catalytic converter reduces the level of NO_x in the exhaust. However, there is also another system that performs the same function in a different way inside the engine combustion chambers. This system, used for many years by the automotive industry, is the exhaust gas recirculation (EGR) system.

14-1 FUNCTION OF AN EGR SYSTEM

An *exhaust gas recirculation system* (Fig. 14-1) reduces the amounts of nitrogen oxide (NO_x) produced inside the engine by controlling peak combustion chamber temperatures. The EGR system accomplishes this by diluting the incoming air/fuel mixture with a small amount of an inert gas. An *inert gas* is one that will not undergo a chemical reaction during the combustion process.

Since engine exhaust gas is relatively inert, manufacturers use it to dilute the air/fuel mixture. This action is done by routing small amounts of this gas (about 6 percent to 14 percent of total exhaust) from the engine's exhaust system to the intake manifold. The incoming concentration of exhaust gas mixes with the air/fuel charge entering the various cylinders and lowers the mixture's ability to produce heat during combustion. This also has the positive effect of maintaining combustion pressure at a level that helps to prevent spark knock or detonation.

Exhaust gas recirculation performs this function by limiting the quality and quantity of the air/fuel charge that actually enters each of the combustion chambers of the engine. Exhaust gas, for example, dilutes the air/fuel mixture with a noncombustible substance because it contains little or no oxygen. In other words, the inert exhaust gas displaces a portion of the oxygen within the highly combustible air/fuel charge, thus reducing the quality of the total mixture reaching each of the cylinders.

Furthermore, since the recirculated exhaust gases are hot, they expand the air/fuel charge within the intake manifold. This action reduces the quantity of combustible material swept into and compressed by each piston within the engine cylinders. The resulting air/fuel and exhaust gas mixture that reaches the combustion chambers is not as powerful when ignited. Thus, it creates less heat than an undiluted charge would otherwise produce.

Not all engine-operating periods produce excessive NO_x levels. For example, an engine creates very small amounts of NO_x at idle and during engine warm-up. Consequently, operation of the EGR system is not always necessary or desirable. Driveability during engine idle and warm-up will be better if the EGR system is not in operation.

The EGR system is also made inoperative during wide-open throttle engine acceleration. This is

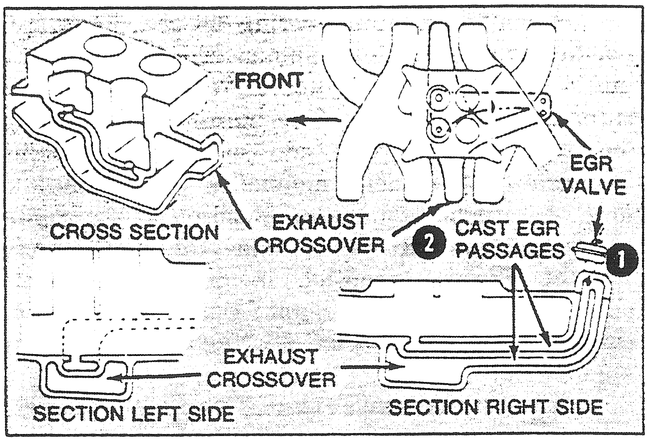


FIGURE 14-2
Floor entry routing of EGR gas within an intake manifold. (Courtesy of Ford Motor Co.)

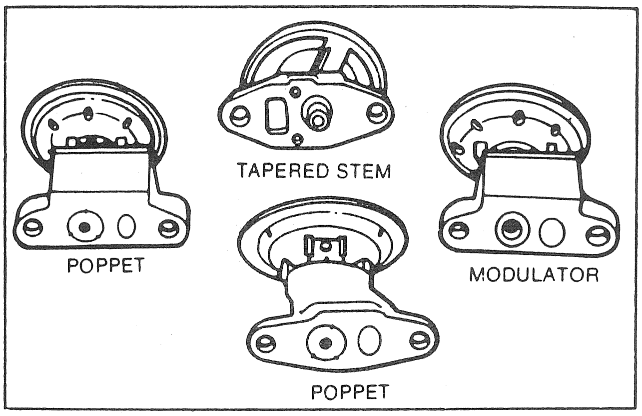


FIGURE 14-3
Types of EGR valves. (Courtesy of Ford Motor Co.)

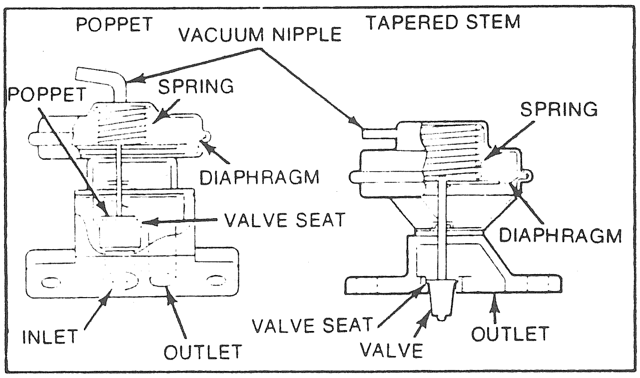


FIGURE 14-4
Internal design of typical EGR valves. (Courtesy of Ford Motor Co.)

done so the engine can provide maximum power.

A typical EGR sytsem will lower NO_x levels under the following conditions: (1) when the engine is at normal operating temperature, (2) when the engine is operating the vehicle at speeds between 30 mph and 70 mph, and (3) when the driver is applying light to moderate pressure on the throttle.

14-2 DESIGN OF A BASIC EGR SYSTEM

Before the advent of computer controls, a basic EGR system consisted of four main components: a redesigned intake manifold, an EGR valve, a vacuum signal source, and some form of thermo-vacuum switch or valve.

Intake Manifold

In order to tap a continuous supply of inert gas from the exhaust system without using external pipes, connections, or a carburetor spacer, a specially designed intake manifold (Fig. 14-2) is used. The type of manifold design depends largely on the engine style and the location of the EGR valve itself.

An intake manifold onto which the EGR valve directly mounts is shown in Fig. 14-2. In this arrangement, the manufacturer casts one additional passage from the exhaust crossover area to the EGR valve, and a second one from the valve to the intake runner floor. Therefore, the manifold has an exhaust crossover that carries gases to preheat the runner floor, and additional passages to transport a specified amount of this inert substance to mix with the air/fuel charge.

EGR Valve

As shown in Fig. 14-2, separating the two additional passages is a vacuum-operated, variable-orifice metering valve, commonly referred to as the *EGR valve.* This valve regulates, or controls, the flow of exhaust gas between the two passages.

There are several types of EGR valves (Figs. 14-3 and 14-4). In a *poppet type,* the valve stem pulls a valve poppet off its seat when a vacuum is applied to a diaphragm. The valve poppets can have various shapes. Moreover, the assembly may have a flow restrictor in the valve body inlet port to regulate gas flow.

In a *tapered type,* the valve end of the stem has a tapered shape (see Fig. 14-4). With this design, the gas flow rate depends on how far the stem end is pulled out of the seat by diaphragm action.

The *modulator type* has an extra disc valve on the stem below the main valve. This disc will restrict

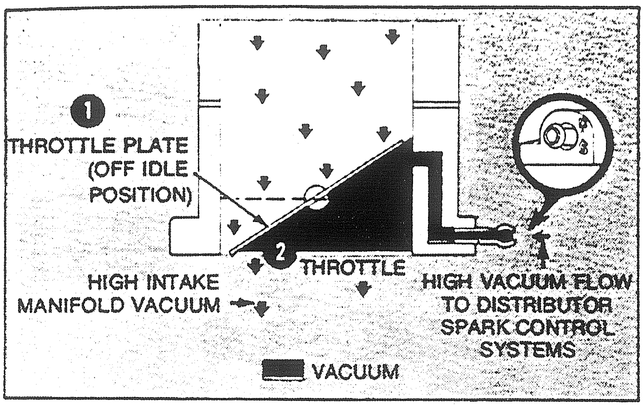


FIGURE 14-5
Spark vacuum port on the carburetor. (Courtesy of Ford Motor Co.)

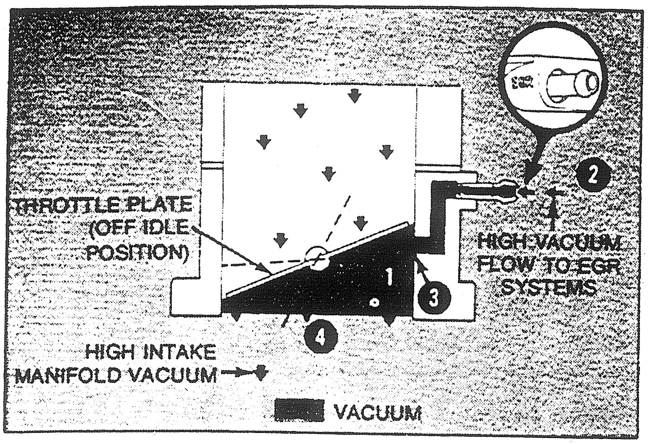


FIGURE 14-6
EGR vacuum port on the carburetor. (Courtesy of Ford Motor Co.)

exhaust gas flow when a high vacuum is applied to the diaphragm. Finally, in all three designs, the inlet port is situated at the valve location and the outlet opposite to it.

Within the assembly is a spring-loaded diaphragm that attaches to the valve stem. The spring side of the diaphragm housing has a nipple that connects via a hose to a vacuum source. The opposite side of this type of assembly has a vent opening to the atmosphere.

In operation, the valve stays in the closed position by the action of the calibrated spring and opens when a given amount of vacuum acts on the diaphragm. For instance, in Fig. 14-4, the spring is holding the diaphragm and the attached poppet or tapered valve in the closed position. As a result, exhaust gases cannot move from the input to the outlet EGR ports and enter the intake manifold.

When the vacuum acting on the diaphragm reaches a predetermined amount, the diaphragm begins to open the valve, and exhaust gas can flow through the assembly. The spring calibrates the amount the valve opens, and therefore the amount of gas flow, by balancing against the force of the vacuum. As a result, the actual position of the poppet or tapered valve meters the flow of exhaust gases into the intake manifold in proportion to the strength of the vacuum signal as it opposes spring tension. Consequently, the EGR valve acts as a variable orifice.

However, even with the EGR valve in the wide-open position, there are still limitations on the amount of exhaust gas that can flow into the intake manifold. In the poppet-type units, the flow restrictor at the inlet port limits the flow when the valve is wide open. On the tapered-type designs, the size of the orifice between the tapered valve and the wall of the seat further restricts exhaust gas movement.

EGR Valve Signal Sources

Manufacturers can use one of three different sources of vacuum to operate an EGR valve: a carburetor spark vacuum port, an EGR vacuum port, or a venturi vacuum tap.

Carburetor Spark Vacuum Port. When an EGR valve is activated by a *carburetor spark vacuum port* (commonly referred to as the *ported vacuum port*), the carburetor has a slot-type port machined into the throttle body a short distance above the position of the closed throttle valves (Fig. 14-5).

With this design, when the throttle valves open off idle during engine acceleration, they expose the slot to a progressively higher percentage of intake manifold vacuum. As a result, there is no signal to the EGR valve when the closed throttle valves are at idle. As the valves open during engine acceleration, the signal increases, which, in turn, opens the EGR valve in proportion to the intensity of the vacuum applied to its diaphragm. In other words, the amount of EGR valve opening and exhaust gas recirculation depends on throttle position and the strength of the vacuum within the intake manifold.

Due to the important fact that the spark or ported signal cannot be more than intake manifold vacuum, the EGR valve cannot function under wide-open throttle acceleration. In other words, as intake manifold vacuum drops extensively during wide-open throttle acceleration, so does the signal to the EGR valve. This action prevents any exhaust gas

recirculation during wide-open throttle operation.

Therefore, an EGR valve that operates according to this signal will open progressively during periods of moderate acceleration between vehicle speeds of about 30 mph to 70 mph. But the valve closes when there is a weak manifold vacuum produced during periods of wide-open throttle operation. It is also closed at engine idle.

EGR Vacuum Port. Some carburetors have an *EGR vacuum port.* With this design, the port is situated just above the closed position of the throttle valves (Fig. 14-6). This port becomes open to intake manifold vacuum when the throttle valves are open slightly off idle. As a result, a high vacuum is then available to fully open the EGR valve just above engine idle. However, as in the case of a ported signal, the EGR port is blocked from manifold vacuum at closed throttle. In addition, at wide-open throttle, the EGR port vacuum is very low due to the reduction in manifold vacuum.

Venturi Vacuum Tap. The third method of providing a signal to an EGR valve is through the use of a carburetor *venturi vacuum tap* (Fig. 14-7) and a control system. The tap is nothing more than a port opening into the throat of the venturi that is at about the same level as the main fuel discharge nozzle location. Like the nozzle, the tap port opening has a low pressure (vacuum) applied on it whenever a considerable amount of air flows through the carburetor.

In operation, the strength of the venturi vacuum signal depends on the velocity of the air flow through the carburetor itself. For example, during engine idle, the air flow through the venturi is very slow. This results in a zero or very low tap vacuum signal. However, as the throttle valves open during engine acceleration, and as air flow increases, the tap signal intensifies in proportion to the rise in the rate of air flow.

However, even when there is a great deal of air passing through the venturi, such as during high engine rpm, the tap signal is too weak to actually operate the EGR valve diaphragm. To overcome this problem, the system requires an amplifier and vacuum reservoir to boost the tap signal sufficiently to open the EGR valve (Fig. 14-8).

In the system shown, a weak venturi vacuum signal is routed to Port V of the amplifier. The much stronger manifold vacuum is routed via a hose to either Port M or S to provide the amplifying power. The vacuum reservoir that connects to Port R maintains sufficient system vacuum when intake manifold vacuum is reduced during open throttle conditions.

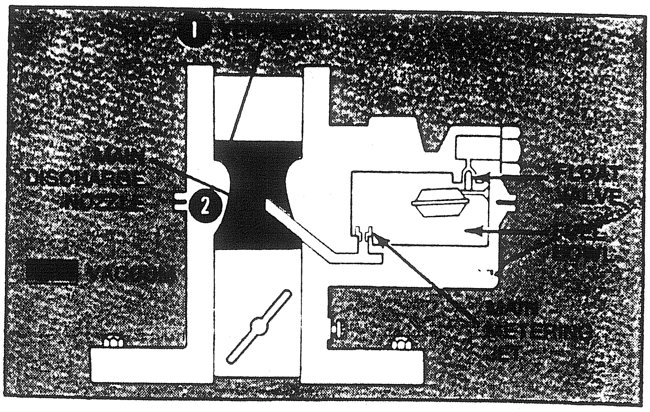


FIGURE 14-7
Carburetor venturi vacuum tap. (Courtesy of Ford Motor Co.)

The amplifier contains a valve and diaphragm mechanism that is, in effect, a vacuum booster. It produces the strong vacuum signal at Port O that is porportional to the weak venturi input signal. A two-port thermostatic device known as a *ported vacuum switch* (PVS) controls the vacuum flow from Port O to the EGR valve nipple.

Coolant-Controlled Vacuum Switch

Figure 14-9 illustrates the thermostatic coolant-controlled PVS just mentioned. The function of this device is to sense coolant temperature and then either cut off the vacuum to the EGR valve when the engine is cold, or connect the vacuum to the EGR valve when the engine is at or near a normal operating temperature.

The PVS contains a wax pellet or bimetallic sensing element that is submerged in the coolant. The sensing element engages with a spring-loaded stem. On the end of the stem is an O-ring seal that acts as a valve.

When the engine temperature is below a specified amount, the spring holds the O-ring seated, as shown in the left drawing of Fig. 14-9. In this case, the carburetor or venturi EGR vacuum at the lower Port S cannot pass through the valve and out of Port E to activate the EGR valve (Fig. 14-10).

As the coolant temperature reaches a predetermined amount, the sensing element expands. This action moves the stem and its attached O-ring off its seat (right diagram of Fig. 14-9). The EGR vacuum can now pass through the PVS and activate the EGR valve (Fig. 14-10).

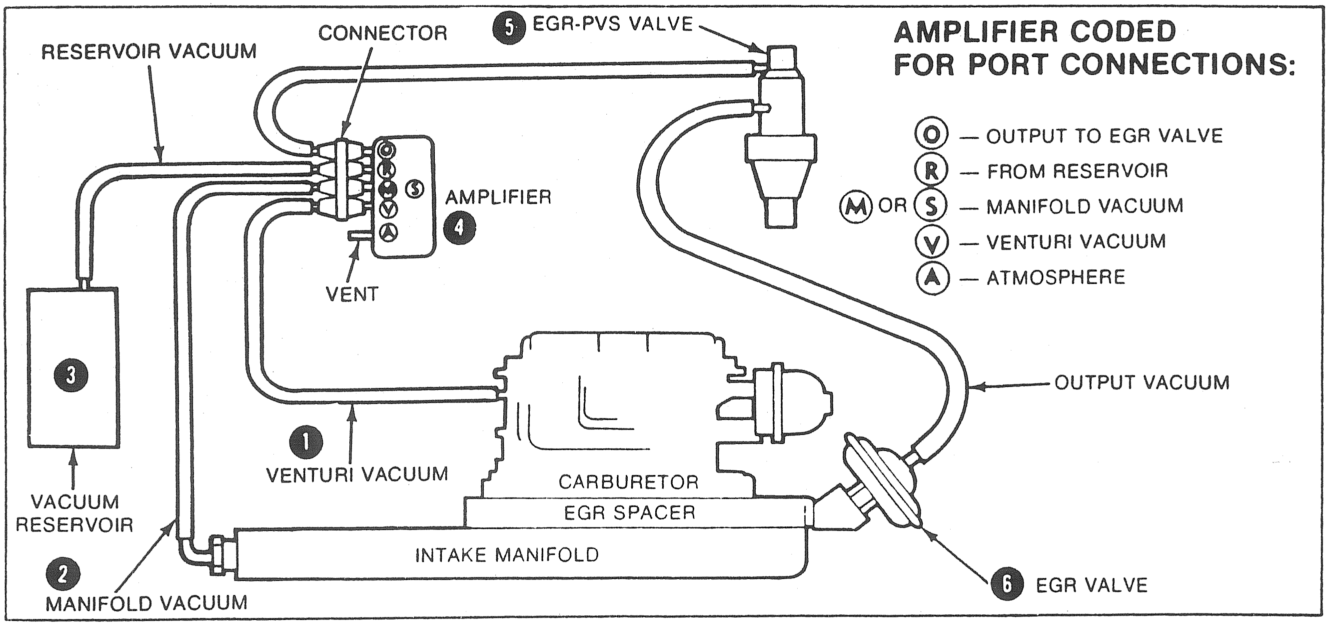


FIGURE 14–8
Typical venturi vacuum amplifier system. (Courtesy of Ford Motor Co.)

14-3 TYPICAL FORD COMPUTERIZED EGR SYSTEM

When Ford changed over to electronic engine controls, the basic EGR system just described was modified somewhat so the ECU could more precisely regulate its function. Before studying the alterations made to accommodate computer control, let's look at one more basic component Ford uses on many of its systems, namely the EGR spacer.

EGR Spacer

In a basic EGR system for V-type engines, Ford uses a spacer (Fig. 14–11). The *EGR spacer* is sandwiched between the carburetor and the intake mani-

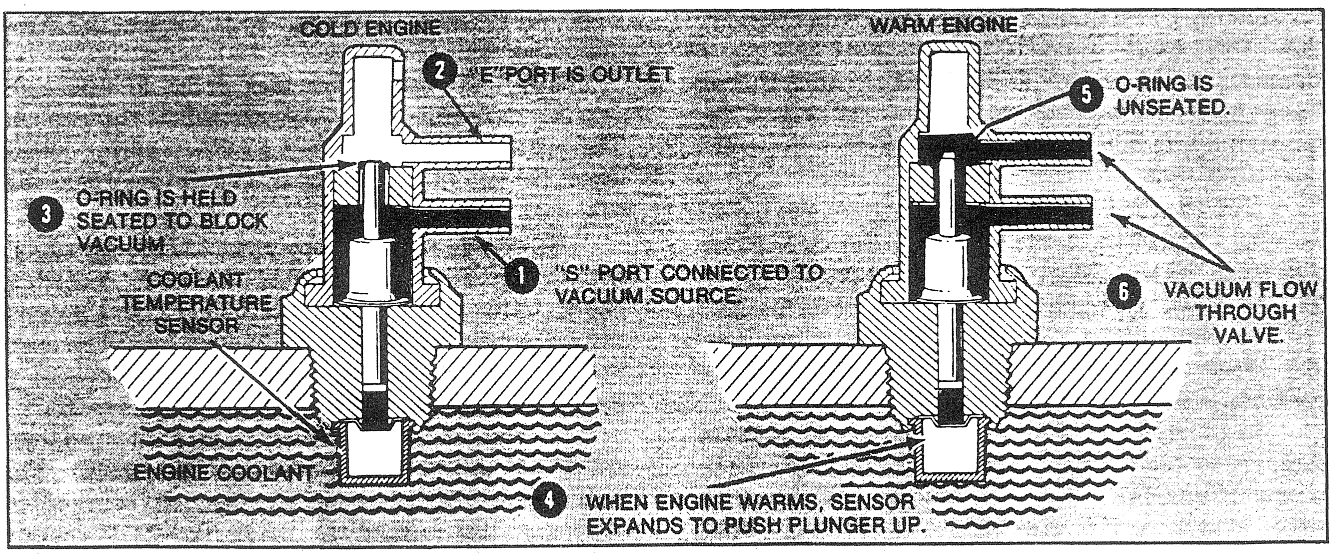


FIGURE 14–9
Typical two-port thermostatic vacuum valve. (Courtesy of Ford Motor Co.)

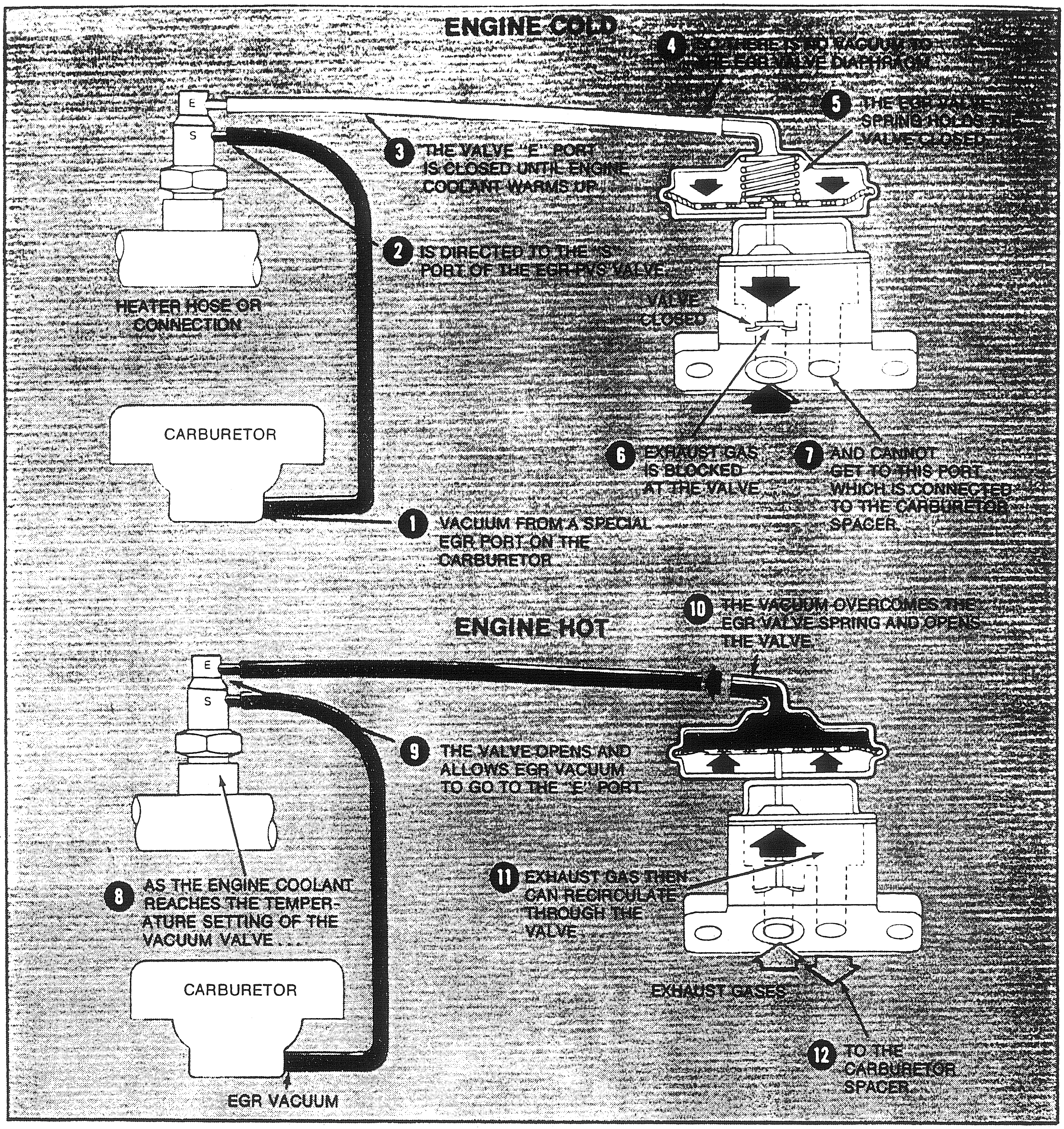


FIGURE 14-10
Operation of the two-port vacuum valve. (Courtesy of Ford Motor Co.)

fold. Gaskets are used above and below the spacer to seal the EGR system and the flow of carburetor-to-manifold air/fuel mixture.

Exhaust gases are admitted to the spacer via a small exhaust crossover passage within the intake manifold. These gases flow through the spacer to the inlet port of the EGR valve. The EGR valve itself bolts to a flange cast into the rear of the spacer.

If the EGR valve opens due to a vacuum signal at the diaphragm, exhaust gas flows through the valve and back to another port of the spacer. Here, the inert gas mixes with the air/fuel charge leaving the carburetor on its way to the intake manifold.

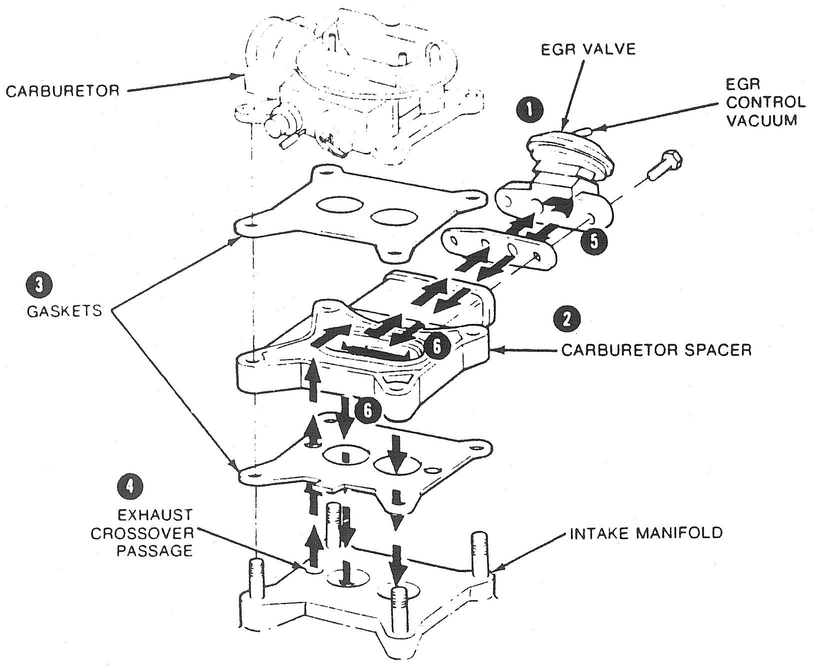


FIGURE 14–11
Ford's EGR spacer. (Courtesy of Ford Motor Co.)

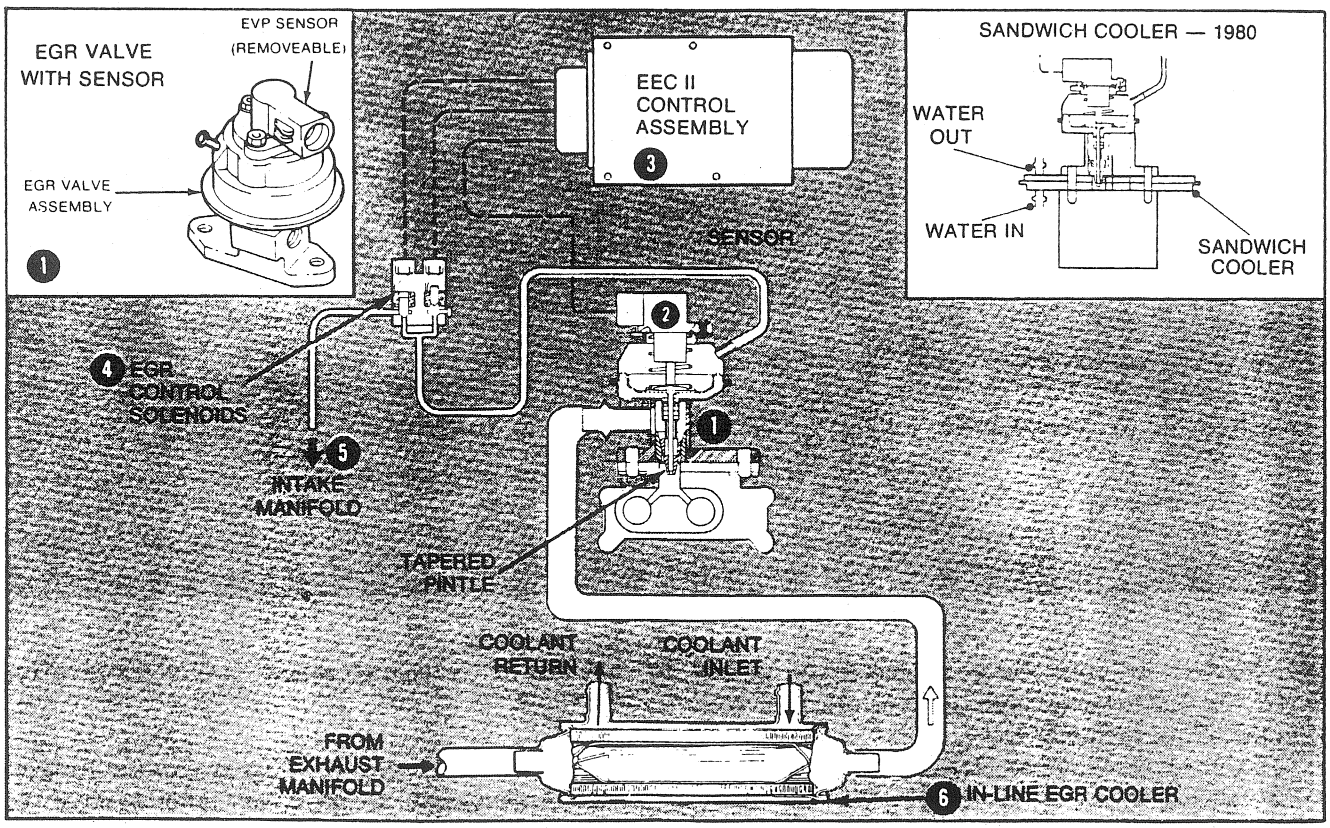


FIGURE 14–12
Typical Ford computerized EGR system. (Courtesy of Ford Motor Co.)

EGR Valve and Sensor

The EGR portion of a typical Ford Electronic Engine Control (EEC) system consists of a combination EGR valve and sensor, EGR cooler, and a pair of control solenoids (Fig. 14-12). The EGR valve itself is similar in design and operates in much the same manner as the single-diaphragm, tapered valve described in Section 14-2.

However, mounted above but still part of the valve assembly is an *EGR position sensor* that has a number of wires connected to the ECA. Through these wires, the sensor sends voltage signals to the ECA relative to the position of the EGR stem and valve. This information informs the ECA just how much exhaust gas is recirculating at any given time. The ECA then compares this information to that received from other sensors within the engine control system and increases or decreases the EGR flow rate.

EGR Cooler

The *EGR cooler* is used on this system to reduce the temperature of the exhaust gases. This helps the inert gas flow better, reduces the tendency for engine detonation, and increases the durability of the EGR valve. The cooler shown in Fig. 14-12 is an inline type. Later systems use a cooler that is sandwiched between the EGR valve and the spacer (see the insert in Fig. 14-12). In either case, the unit is a heat exchanger that uses engine coolant as the cooling medium.

In operation, the exhaust gas must pass through the cooler on its way to the EGR valve. The coolant flowing through a compartment in the cooler assembly removes excess heat from the exhaust gas before it enters the EGR valve.

Solenoids

The computerized Ford EGR system shown in Fig. 14-12 has twin solenoids. These *EGR solenoids* control the operation of the EGR valve by turning its vacuum signal on and off. The two solenoids mount together on a bracket usually bolted to the engine rocker-arm cover.

The solenoids connect by wiring to the ECA. The ECA continuously analyzes the information it receives from all the system sensors and electrically changes the position of the solenoid plungers. Each plunger has a pointed tip that acts as a valve.

As in the case of the Ford and Chrysler air in-

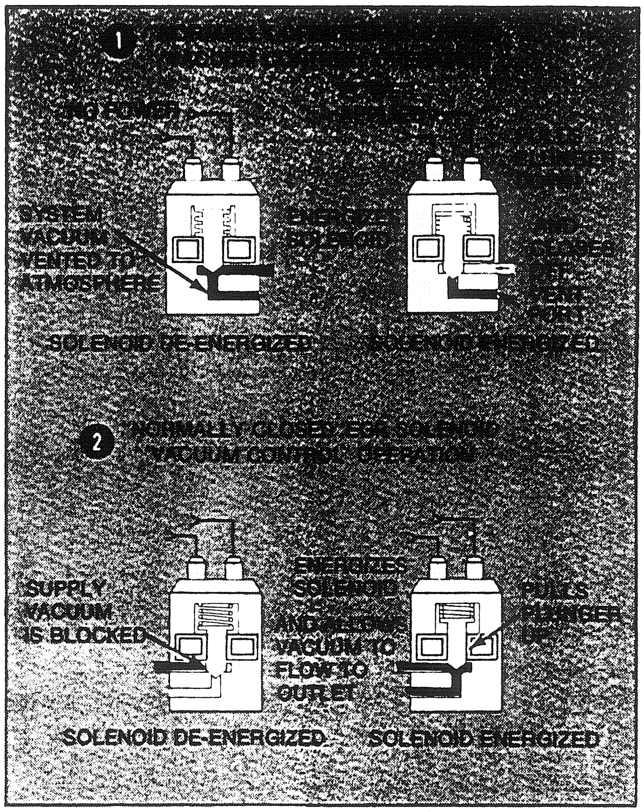


FIGURE 14-13
EGR solenoids. (Courtesy of Ford Motor Co.)

jection switching solenoids, these assemblies have battery voltage supplied to their positive terminal whenever the ignition switch is on. To energize a solenoid, the ECA just has to complete its ground circuit.

One of the units is a vent solenoid (Fig. 14-13) that is usually open. This means that when the plunger valve in this assembly is up (i.e., the solenoid is de-energized), the vacuum signal to the EGR valve vents to the atmosphere. This action causes the EGR valve to close.

However, when the ECA completes the ground circuit of the vent solenoid, the plunger is pulled down. The plunger valve now closes the vent port. (See the upper diagram of Fig. 14-13.) If the other solenoid is open, the vacuum can now act on the EGR valve.

The second solenoid is a vacuum control unit that is usually closed. Therefore, when the ECA de-energizes it, the plunger is spring loaded to the down, or closed, position. This cuts off the vacuum signal to the EGR valve. If the ECA completes the ground circuit of the solenoid, it pulls the plunger up and opens the vacuum signal circuit to the EGR valve. (See the lower diagram of Fig. 14-13.)

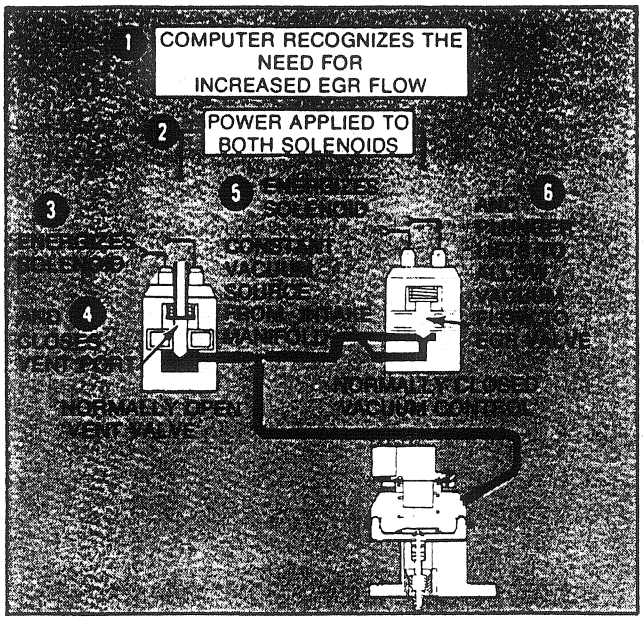


FIGURE 14-14
Solenoid action as the ECA increases EGR flow. (Courtesy of Ford Motor Co.)

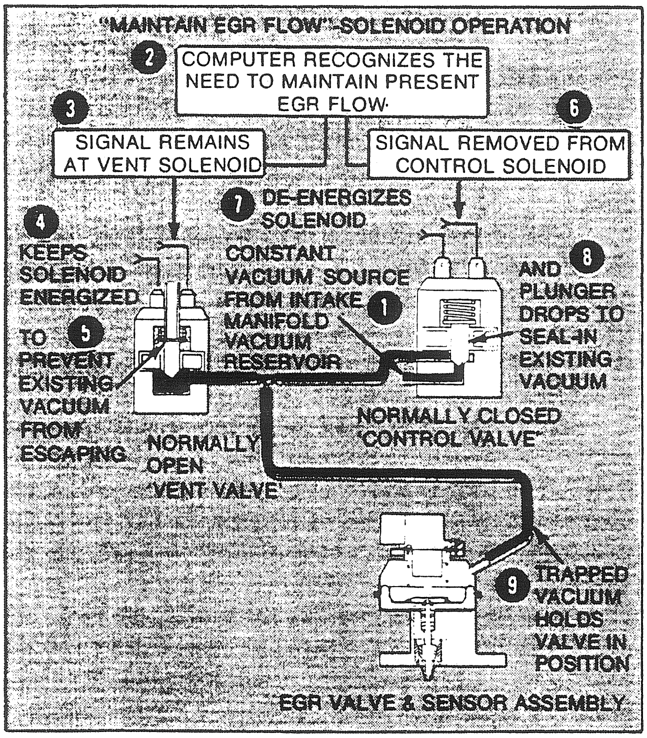


FIGURE 14-15
Solenoid action as the ECA maintains EGR flow. (Courtesy of Ford Motor Co.)

System Operation

After receiving data from the engine sensors, the ECA calculates the correct amount of EGR flow required for the existing conditions. The ECA also checks the EGR valve position information from its sensor and decides if the present exhaust gas flow should be increased, maintained, or decreased. If EGR flow needs to be increased, the ECA grounds both solenoids.

This action closes the normally open vent port and opens the normally closed vacuum control port (Fig. 14-14). This action increases the vacuum to the EGR diaphragm, which opens the EGR valve in proportion to the strength of the signal. Thus, EGR flow is increased.

To maintain a given amount of EGR flow, the ECA breaks the ground circuit of the vacuum control solenoid. As a result, the solenoid plunger drops to seal the existing vacuum in the circuit to the EGR valve (Fig. 14-15).

Since the other solenoid remains energized, the vent remains closed. With a given amount of vacuum trapped in the EGR diaphragm circuit, its valve remains in a given position, thus allowing a set amount of exhaust gas to flow.

If the ECA recognizes a need to decrease EGR flow, it breaks the ground circuit for both solenoids and they de-energize (Fig. 14-16). This action vents any vacuum in the EGR diaphragm circuit and cuts off its incoming vacuum signal. Consequently, the EGR diaphragm closes the valve and stops the exhaust gas flow.

One thing to keep in mind is that the ECA checks the actual EGR valve position about ten times every second. It then compares the actual with the desired position and makes any necessary adjustments to maximize valve position accuracy. This continuous monitoring of valve position provides precise control of EGR flow for improved economy and driveability.

14-4 TYPICAL CHRYSLER TIME-DELAY AND COMPUTERIZED EGR SYSTEMS

In recent years, Chrysler has used both time-delay and computer-controlled EGR systems that are similar in appearance (Fig. 14-17). Both systems use a single-diaphragm EGR valve similar to the one discussed in Section 14-2. The main difference between the two versions of the system lies in the method used to control the vacuum to the EGR valve.

Time-Delay System

In the first version, the vacuum signal for the EGR diaphragm is controlled part of the time by a *time-delay system.* This system prevents exhaust gas recirculation when the engine is cold and for about 35 seconds after the driver turns on the ignition switch. This action improves engine starting, warm-up, and initial vehicle driveability. When the engine is cold, even fuel distribution is important to keep the engine running smoothly. Also, NO_x formation is low when the engine is cold.

The delay function is for a similar reason. After a hot engine shut down combined with a heat soak period, fuel distribution may be uneven due to percolation. The time-delay period allows the engine to stabilize before EGR begins. This represents a short interval when NO_x formation would be low due to cooler initial combustion temperatures.

Delay Timer and Solenoid

The time-delay system consists of a timer, solenoid, charge temperature switch, and a coolant temperature switch. The *delay timer* mounts onto the firewall inside the engine compartment. Its function is to electrically activate the solenoid for about 35 seconds once the ignition switch is on.

The solenoid has a plunger that controls two vacuum ports. These ports lie between the vacuum amplifier and the coolant control engine vacuum switch (see Fig. 14-17). When the relay energizes the solenoid, it cuts off and vents the vacuum signal between the amplifier and the vacuum switch. Therefore, if the engine is at normal operating temperature, the vacuum signal cannot reach the EGR valve. However, after 35 seconds, the relay de-energizes the solenoid, and its plunger now permits the amplifier signal to reach the EGR valve. This permits normal exhaust gas flow.

Charge Temperature Switch

Installed into an intake manifold runner is a *charge temperature switch (CTS).* The function of this switch (Fig. 14-18) is to provide a signal to the delay timer, and therefore the solenoid, relative to the temperature of the air/fuel charge within the manifold. For example, when the charge is below 60°F (16°C), the CTS closes to provide a ground for the solenoid circuit. As a result, the solenoid energizes. This prevents normal EGR operation.

When the air/fuel charge reaches above 60°F

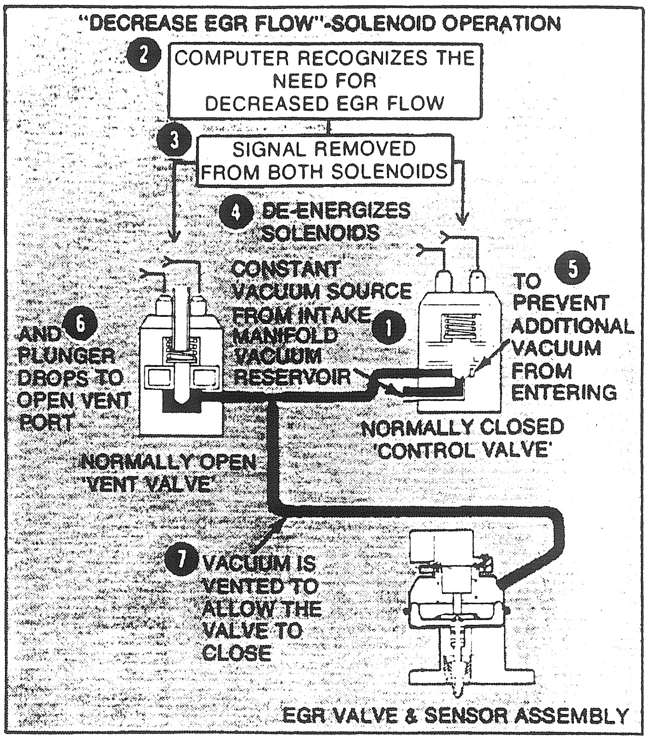


FIGURE 14-16
Solenoid action as the ECA decreases EGR flow. (Courtesy of Ford Motor Co.)

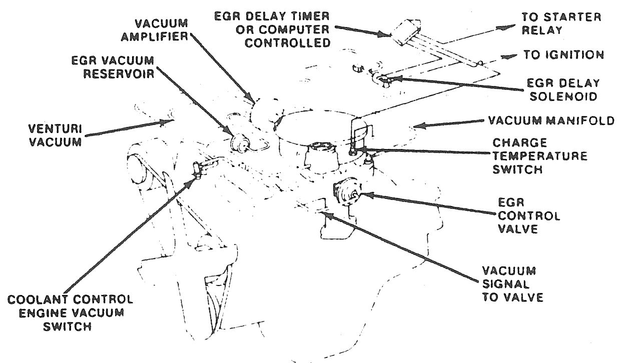


FIGURE 14-17
Chrysler computerized or electronically controlled EGR system. (Courtesy of Chrysler Motors Corp.)

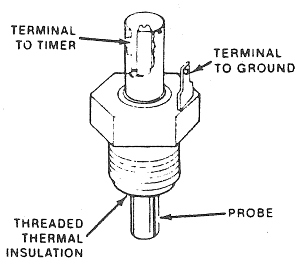


FIGURE 14-18
Charge temperature switch. (Courtesy of Chrysler Motors Corp.)

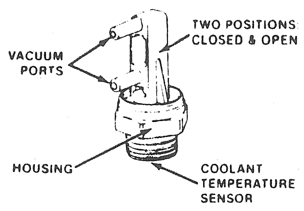


FIGURE 14-19
Coolant temperature vacuum switch. (Courtesy of Chrysler Motors Corp.)

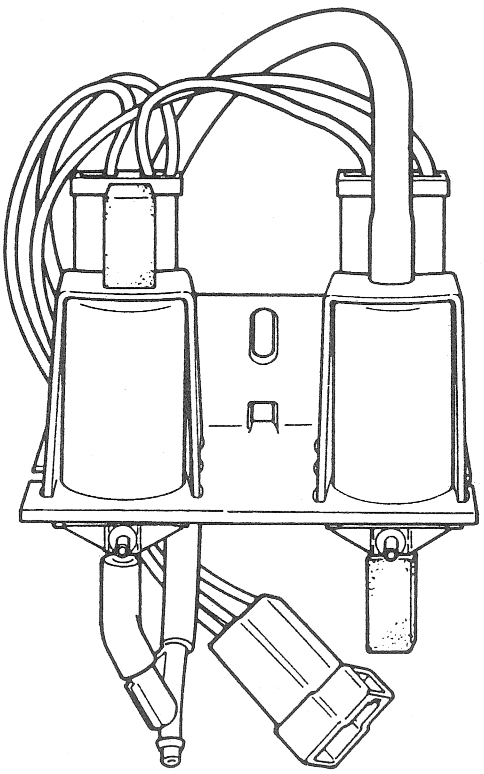


FIGURE 14-20
EGR and air switching solenoids. (Courtesy of Chrysler Motors Corp.)

(16°C), the CTS opens the solenoid ground circuit to de-energize the solenoid. However, the timer will, for its normal 35-second delay period, provide a secondary ground to keep the solenoid energized. After this period, the relay de-energizes the solenoid for normal EGR operation.

Coolant Control Engine Vacuum Switch

Some vehicle models with the EGR delay system use a *coolant control engine vacuum switch*

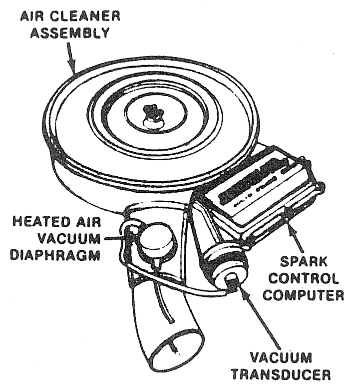


FIGURE 14-21
Spark control computer. (Courtesy of Chrysler Motors Corp.)

(CCEVS) in place of the CTS (Fig. 14-19). This device is similar to the Ford two-port PVS described in Section 14-3. In this installation, the vacuum switch blocks the vacuum signal from the solenoid to the EGR valve when the engine is cold. However, when the coolant is hot, the switch opens so that the vacuum signal can pass through to the EGR valve.

With this arrangement, the CCEVS prevents EGR operation until the engine reaches a normal operating temperature. At this point, the delay timer prevents EGR operation for the 35-second period described above.

Computer-Controlled Solenoid

The delay timer and delay solenoid are not needed in computer-controlled vehicles. In their place, the system uses another type of solenoid and a spark control computer (Figs. 14-20 and 14-21). The solenoid is one of an identical pair, one for the EGR system and the other for the switching valve of the air injection system. Both are solenoid-operated vacuum valves that are normally closed. In operation, they not only turn the vacuum signal off or on to the appropriate unit but also vent a given circuit when de-energized.

The computer-operated *EGR solenoid* also has two vacuum ports. One port connects via a hose to the EGR valve while the other connects to the vacuum amplifier. When the solenoid is de-energized by the computer, the vacuum signal to the EGR valve is cut off and the circuit vents to the atmosphere.

Notice in Fig. 14-20 that the solenoid requires two wires. This indicates that the system supplies power to the solenoids at all times the ignition switch is on. To complete the circuit to one or both of the solenoids, the computer just provides a ground circuit.

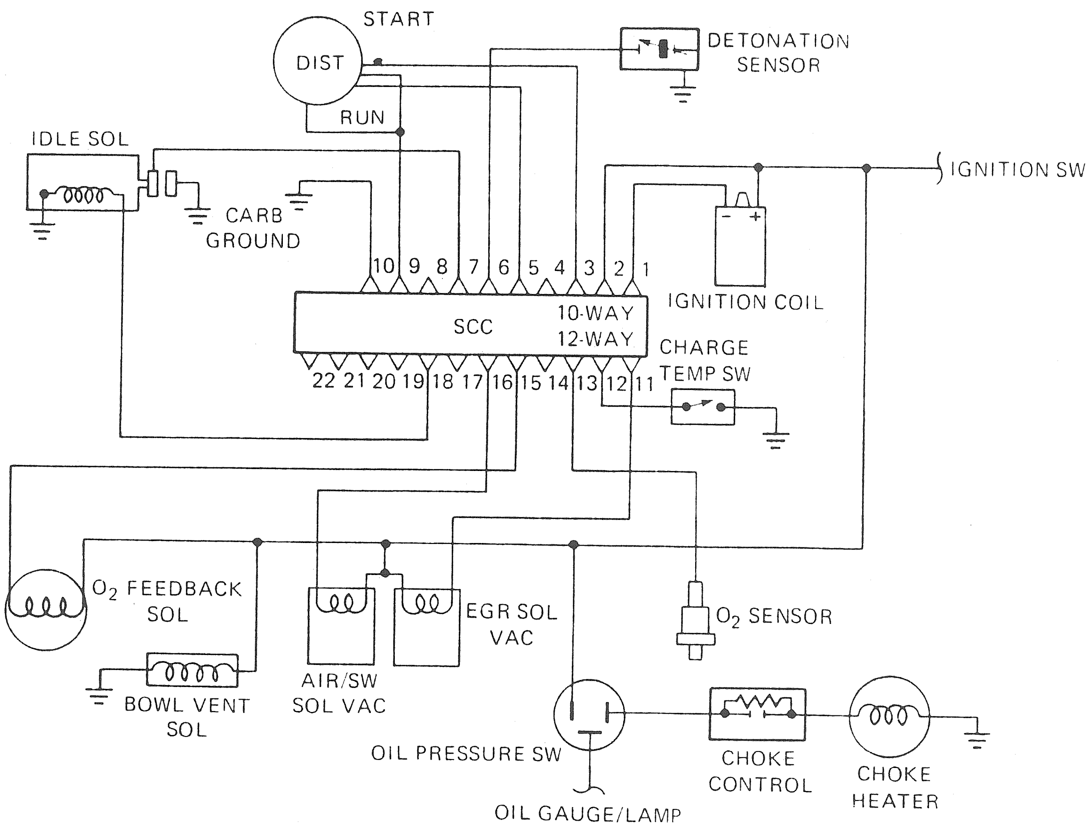


FIGURE 14-22
Schematic of a Chrysler computerized engine control system. (Courtesy of Chrysler Motors Corp.)

Spark Control Computer

The heart of the system is the *spark control computer* (SCC). Within the SCC is programmed information that identifies engine size, transmission type, engine operating temperature, spark advance requirements, basic timing, necessary carburetor mixtures for all running modes, and specified periods for air injection switching or exhaust gas recirculation.

To perform this function, the SCC receives data from the following switches or sensors (Fig. 14-22): oxygen, detonation, distributor, carburetor, charge temperature, coolant temperature, and vacuum transducer.

Operation of the Solenoid

As shown in Fig. 14-22, the EGR vacuum solenoid has power supplied to it via the ignition switch. Whenever the SCC determines that EGR is needed, it internally completes a ground circuit for Pin 11. With Pin 11 grounded, the circuit through the EGR solenoid is complete, and it energizes.

This action opens the solenoid vacuum valve. As a result, a venturi vacuum signal can act on the EGR diaphragm, and exhaust gas recirculation begins. The solenoid remains open as long as EGR is necessary. The actual amount of flow is determined by two factors: the strength of the venturi vacuum signal on the diaphragm itself, and the computer on/off cycle time for the solenoid ground circuit.

14-5 TYPICAL GENERAL MOTORS COMPUTERIZED EGR SYSTEM

The typical General Motors system, shown in Fig. 14-23, is quite similar in design and operation to the Chrysler system. The system consists of a single-diaphragm EGR valve and one or more ECM-controlled solenoids.

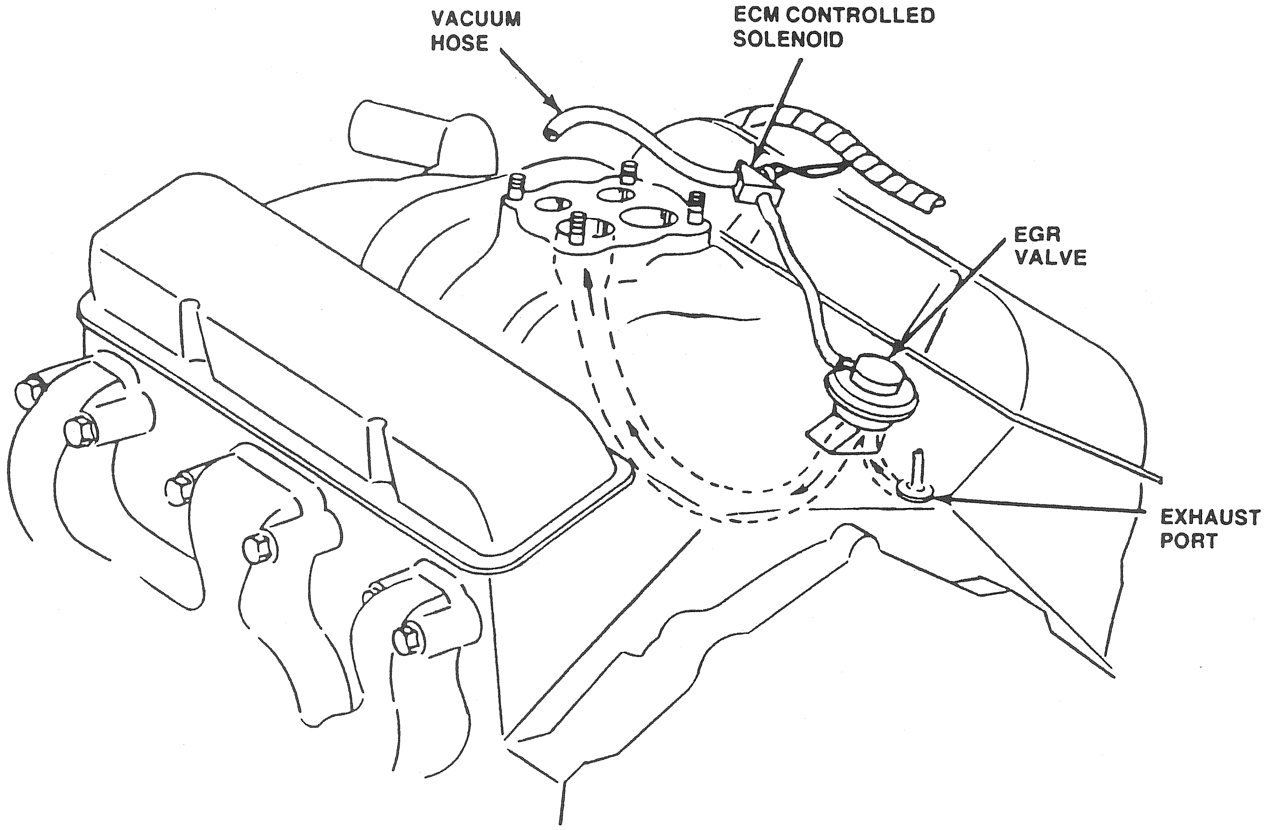


FIGURE 14-23
Typical General Motors computerized ERG system. (Courtesy of General Motors Corp.)

Single-Diaphragm EGR Valve

The single-diaphragm EGR valve contains a diaphragm connected by a shaft to a tapered valve (Fig. 14-24). The diaphragm is spring loaded to keep the valve closed when there is no vacuum signal.

The vacuum signal that operates the diaphragm against spring tension comes from the EGR port on the carburetor. As the throttle opens during acceleration, the EGR port supplies a signal to the diaphragm. The signal pulls the diaphragm up and opens the EGR valve. Variations in throttle position alter the strength of the signal and therefore the position of the EGR diaphragm and valve. This action controls the amount of exhaust gas that is recirculated.

EGR Solenoid

As mentioned, the General Motors system may contain one or two electric EGR solenoids (Fig. 14-25). No matter the number, the solenoids are electrically activated vacuum valves.

If the system uses just one solenoid, it has a bleed orifice, and the assembly acts to control venting of the EGR signal to the diaphragm (Fig. 14-26). When this normally closed solenoid is energized, the signal bleeds off to the atmosphere via the orifice.

When the system has two solenoids (Fig. 14-27), one solenoid, as mentioned, acts as a vent for the diaphragm signal. The second solenoid controls the carburetor vacuum signal to the EGR valve. With this normally open solenoid energized, the vacuum signal is prevented from reaching the EGR valve.

The electronic control module (ECM), after receiving input from system sensors, regulates the operation of the solenoids. The ECM performs this function by providing a ground circuit for the solenoid.

Solenoid Operation

On the single solenoid system, the ECM completes the ground circuit for the solenoid below a given en-

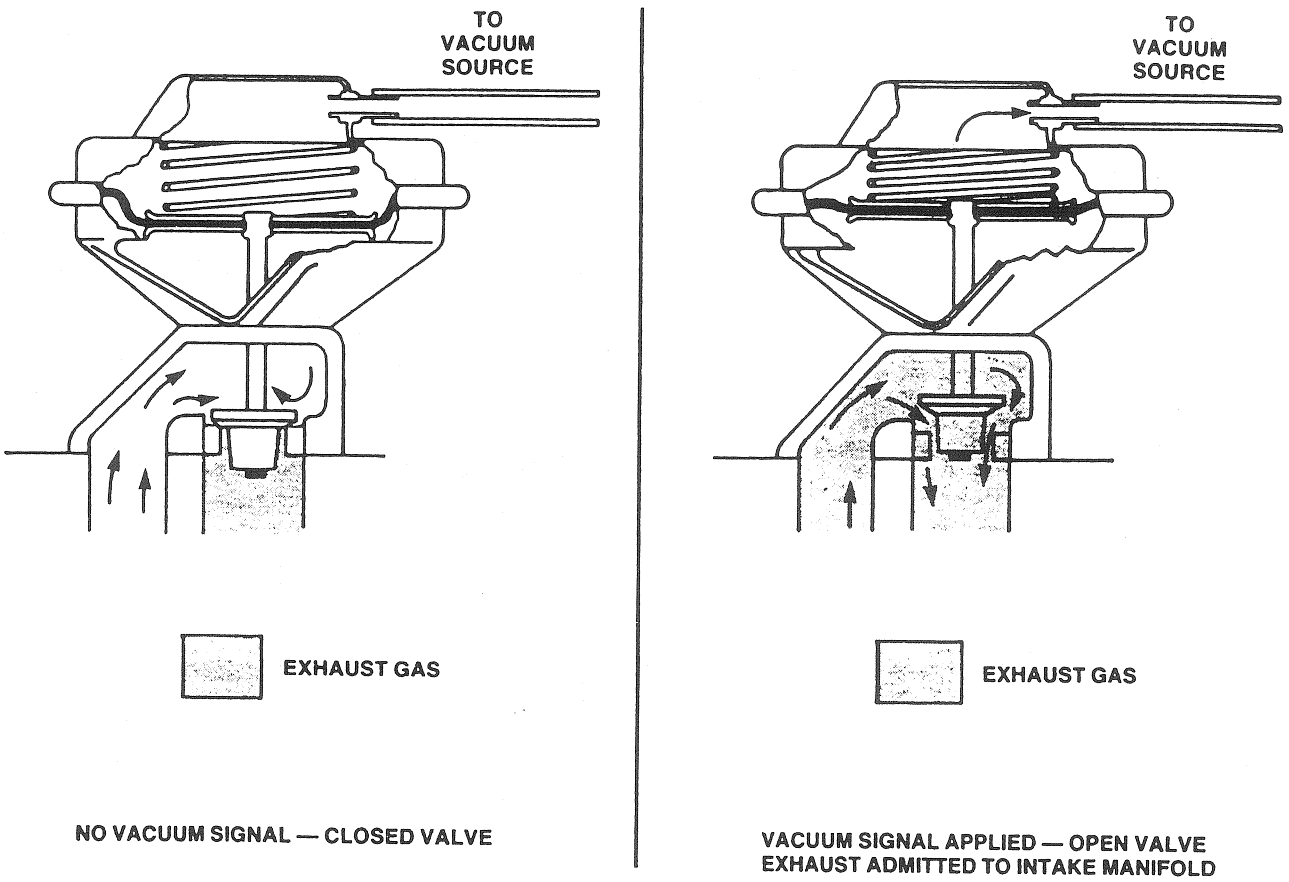


FIGURE 14-24
Design and operation of a single-diaphragm ERG valve. (Courtesy of General Motors Corp.)

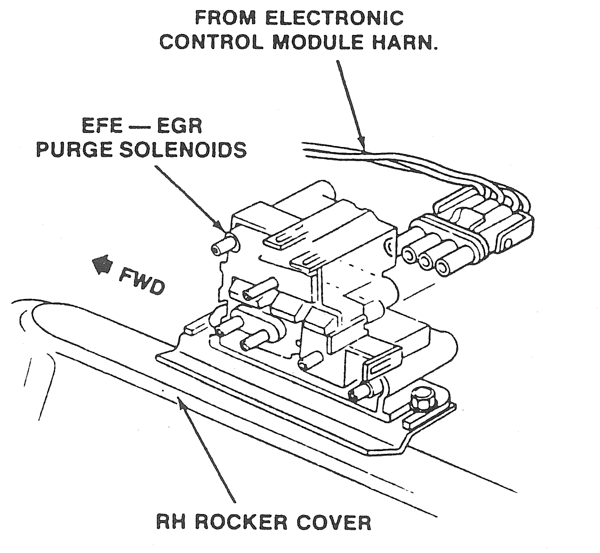


FIGURE 14-25
Early fuel evaporation (EFE) and EGR solenoids [Courtesy of General Motors Corp.)

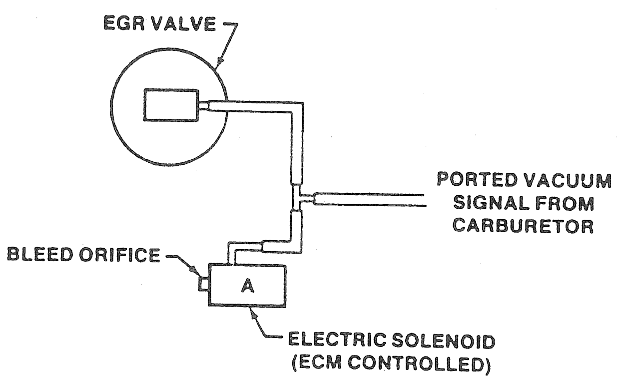


FIGURE 14-26
EGR operation with a single solenoid with a bleed orifice. (Courtesy of General Motors Corp.)

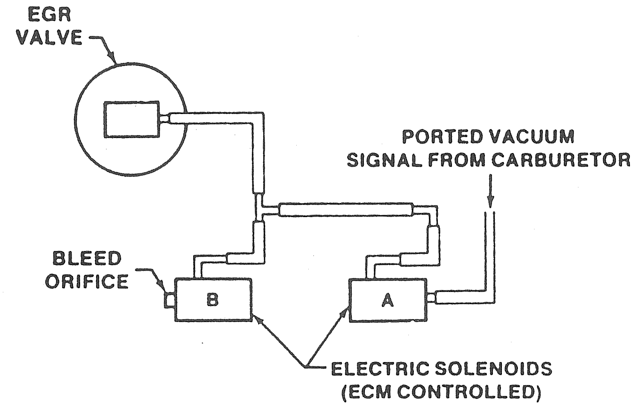


FIGURE 14-27
EGR operation on a system using two solenoids. (Courtesy of General Motors Corp).

gine temperature. This action energizes the solenoid, and it vents the EGR diaphragm vacuum signal to the atmosphere (see Fig. 14-26). However, as the engine warms up to a calibrated temperature, the ECM opens the solenoid ground circuit. The solenoid now de-energizes and closes the orifice vent.

If the system uses two solenoids, the vent assembly operates as mentioned above (see Fig. 14-27). When the ECM grounds the second solenoid below a given temperature, it energizes. The vacuum valve on the solenoid, which is normally open, will close and cut off the signal to the EGR diaphragm.

At a calibrated engine temperature, the ECM breaks the ground circuit, and the vacuum control solenoid de-energizes. Thus, its valve opens. At this point, the carburetor vacuum signal can act on the EGR diaphragm, and exhaust gas recirculation begins. The amount of EGR depends on the strength of the vacuum signal plus the on/off time of the ECM solenoid ground circuits.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. What two systems described in this chapter use a vent and a vacuum-control solenoid [14-3 and 14-5]?
2. How does the EGR system reduce NO_x emissions [14-1]?
3. What is the main difference between Chrysler's time-delay and computerized systems [14-4]?
4. Describe the differences among the three types of EGR valves presented in this chapter [14-2].
5. Ford eliminates what structural component through the use of a carburetor spacer [14-3]?

REVIEW

1. With the engine operating at normal temperature, what is the condition of the solenoids in the General Motors system [14-5]?
   a. both de-energized
   b. both energized
   c. one de-energized, the other energized
   d. none of these
2. A basic EGR system should function at what vehicle speeds [14-1]?
   a. 0 mph to 30 mph
   b. 30 mph to 70 mph
   c. all speeds
   d. stationary operation only
3. When does the General Motors EGR system receive its vacuum signal [14-5]?
   a. with the throttle valves wide open
   b. with the throttle valves one-third open
   c. as the throttle valves just crack open
   d. with the throttle valves closed
4. How does the spark control computer energize the EGR solenoid [14-4]?
   a. by providing a voltage to the solenoid
   b. by providing a ground for the solenoid
   c. by providing a source of vacuum
   d. by providing a source of air pressure
5. Engine exhaust is used as an inert gas by the EGR system because it does not contain what [14-1]?
   a. nitrogen.
   b. air.
   c. oxygen.
   d. gasoline.

6. How long does a Chrysler time-delay system prevent EGR system operation [14-4]?
   a. 35 seconds after engine start-up
   b. 15 seconds after engine start-up
   c. 10 seconds after engine start-up
   d. 5 seconds after engine start-up
7. What can limit the maximum amount of flow from an EGR valve [14-2]?
   a. the restriction built into the valve
   b. the design of the tapered valve
   c. both a and b
   d. neither a nor b
8. How many solenoids does the Ford EGR system use [14-3]?
   a. two
   b. one
   c. three
   d. none
9. Which of the three sources of vacuum opens the EGR valve the fastest as the throttle valves begin to open off idle [14-2]?
   a. auxiliary port
   b. venturi port
   c. ported port
   d. EGR port
10. Which component within the Ford EGR system informs the computer as to the quantity of exhaust gas flow [14-3]?
    a. EGR valve position sensor
    b. EGR valve
    c. solenoid
    d. coolant temperature vacuum switch

Chapter 15

TESTING A TYPICAL COMPUTERIZED EGR SYSTEM

OBJECTIVES

After reading and studying this chapter, you will be able to

- inspect the routing of vacuum hoses within an exhaust gas recirculation (EGR) system.
- clean a typical EGR valve.
- test typical ported and venturi vacuum-operated EGR systems.
- check a thermostatic vacuum switch for serviceability.
- test an EGR time delay system.
- check an EGR position sensor.
- test an EGR solenoid and its power and on/off circuitry.

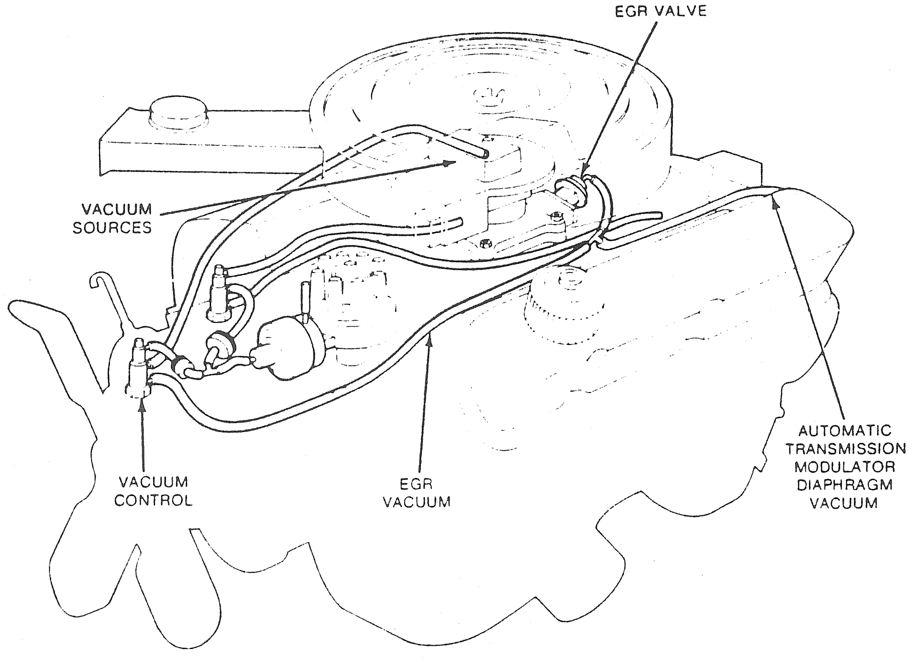


FIGURE 15-1
Typical EGR system vacuum hose routing. (Courtesy of Ford Motor Co.)

The amount of exhaust gas recirculation (EGR) flow is calibrated carefully for every engine configuration. If there is too much or too little flow, it can create performance problems by adversely altering the engine's air/fuel ratio. If the flow is too great, the quality and quantity of combustible mixture is reduced. If the flow is insufficient, the quality and quantity of the charge are increased.

Typical problems that occur due to malfunctions in EGR flow include the following:

1. Rough idle. This is due to excessive flow caused by an EGR valve that is stuck open, a ported vacuum switch (PVS) that has failed to close, deposits on the EGR valve or seat, a defective vent solenoid or circuit, a malfunctioning EGR position sensor, or loose EGR valve mounting bolts. Loose mounting hardware will cause the air/fuel mixture to lean out due to a vacuum leak. Vacuum leaks can also cause a hissing noise.

2. Surge, stall, or won't start. This can be the result of an EGR valve that is stuck open.

3. Detonation or spark knock. This problem can result from a loss or reduction in EGR flow. This condition can be caused by an EGR valve that is stuck closed, an EGR valve diaphragm that is leaking, EGR flow passages that are restricted, a problem in the EGR vacuum source, the EGR system being disconnected, an EGR position sensor that is faulty, or an EGR vacuum control solenoid or its circuit that is defective. *Detonation from any cause is a serious problem that can destroy the engine.*

4. Lead poisoning. If leaded gas is improperly used, it can leave deposits on the EGR valve and seat, causing a restriction in flow.

It would not be possible in the space available in this chapter to adequately cover testing and service information on all the computerized EGR systems in current use. The following sections provide commonly used general diagnosis and testing procedures to familiarize you with the processes. *For complete details on specific procedures for a given year and model, always refer to the appropriate service manual, or damage to system components may result.*

15-1 GENERAL EGR SYSTEM SERVICE

Before actually discussing the testing of the EGR system and its components, let's first examine some general service tips dealing with system inspection, parts replacement, and EGR valve cleaning.

System Inspection

The first step in troubleshooting a malfunction in EGR flow is always a visual inspection of the sys-

tem. When inspecting an EGR system, always check the physical condition and proper routing of all its vacuum hoses. The best way to determine if all vacuum hoses connect to the correct component is to check their routing against an EGR vacuum or system diagram (Fig. 15-1). This diagram illustrates not only the proper hose routing but also all the system vacuum components. You can find a diagram like the one in Fig. 15-1 or a schematic similar to it in the vehicle service manual or, in most cases, on a decal located within the engine compartment.

Parts Replacement

The removal and subsequent reinstallation of most EGR system components is not a very difficult task. However, when replacing parts, remember the following tips:

1. Make certain that the replacement part is an exact duplicate of the one that is defective.

2. Use a thin coating of nonhardening sealer around the threads of a coolant-controlled vacuum switch before installing it.

3. When replacing a part that has a number of vacuum hose connections, use masking tape and a marking pen to identify vacuum hose locations. This assists in reinstalling the hoses in their correct positions.

4. Always use a new gasket when replacing an EGR valve.

5. Torque all component hardware to factory specifications to prevent a vacuum or exhaust leak.

Cleaning an EGR Valve

There are several acceptable methods of cleaning an EGR valve. The procedure used will depend on the particular valve design and the equipment that is available. However, before attempting to clean an EGR valve assembly, remember the following important points:

- Always remove an EGR valve from the engine before trying to clean it.

- Be careful not to push on the valve diaphragm during the cleaning procedure because this may damage or tear it.

- When using a manifold heat control valve solvent or its equivalent to clean the valve area, be careful not to get any of the substance on the diaphragm.

Abrasive Cleaning. With these tips in mind, you can clean an EGR valve with an abrasive-type cleaning machine using the following procedure:

1. Remove all the exhaust deposits from the port areas and mounting surface of the valve with a wire brush or power-driven wire wheel.

2. Clean the valve seat and pintle area by inserting the port opening over an abrasive-type spark plug cleaning machine. Apply an abrasive blast to the area for about 30 seconds.

3. Connect the hose from a vacuum pump to the EGR nipple (Fig. 15-2). Smoothly apply two inches to ten inches of vacuum to the valve diaphragm. While applying the vacuum, watch the valve stem movement. The stem must move evenly without sticking or chatter. Also, there should be no valve noise or vibration. If the diaphragm does not hold the applied vacuum or the stem binds or chatters even after cleaning, replace the assembly.

4. Reinstall the valve inlet port into the opening in the cleaning machine. Apply an abrasive blast for another 30 seconds.

5. Inspect the valve. If all the exhaust deposits have not been removed, repeat step 4.

6. Clean the valve seat and pintle area with compressed air.

7. Bleed the vacuum off the diaphragm and remove the pump hose from the nipple.

Solvent Cleaning. To clean the EGR valve with a manifold heat control valve solvent, do the following:

1. Apply a liberal amount of the solvent to the valve, seat, and inlet port area.

Note: Be careful when applying this solvent not to spill any of it onto the diaphragm. The solvent may cause diaphragm failure.

2. Allow the solvent about 30 minutes to soften up the deposits.

3. Connect a vacuum pump hose to the diaphragm nipple and apply two inches to ten inches of vacuum. Watch the action of the valve stem for sticking or chatter.

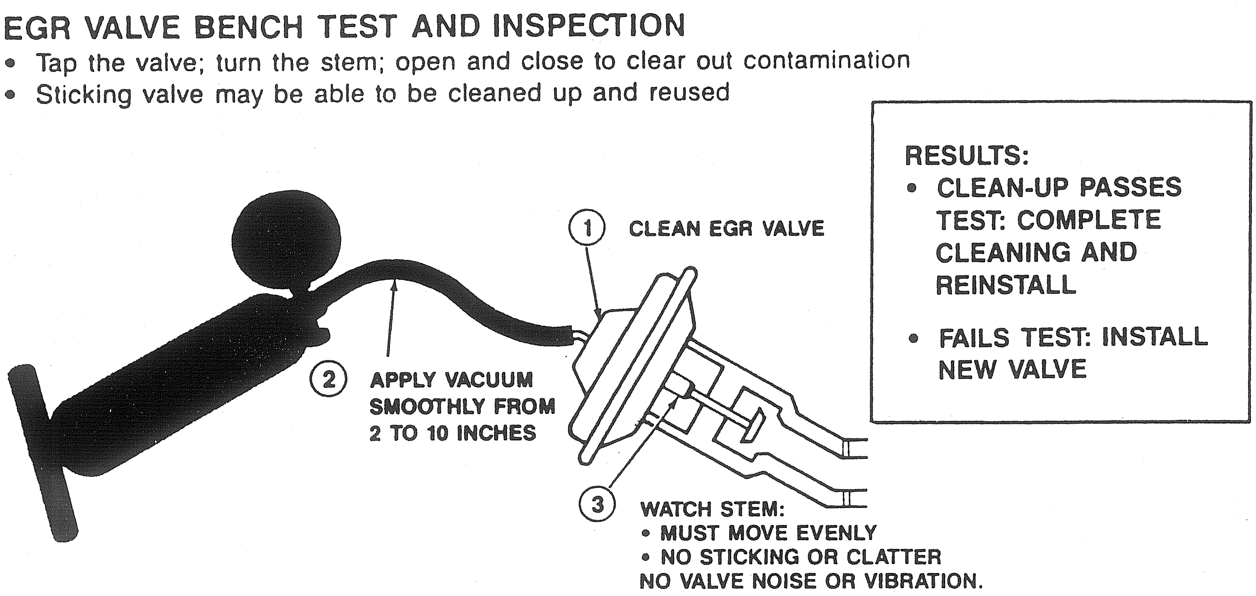


FIGURE 15-2
Actuating the EGR valve during cleaning (Courtesy of Ford Motor Co.)

Caution: Do not push on the diaphragm to open the valve; use a vacuum source.

4. Use a sharp-edged tool to carefully scrape the loosened deposits from the valve head and seat. After cleaning the valve, if you notice excessive wear on the stem, valve, or seat, or if the stem sticks or chatters, replace the assembly.

5. Bleed the vacuum off the diaphragm and remove the hose from the nipple.

15-2 TESTING THE OPERATION OF AN EGR SYSTEM

There are a number of methods used to check the basic operation of an EGR system. The method used depends greatly on whether the stem of the EGR valve is visible from the outside or not. If the stem is visible, you can use the following procedure to check the serviceability of the system.

Operational Check for Valve Movement

To test for valve stem movement on an operating engine, do the following:

1. Following the manufacturer's instructions, connect a tachometer to the engine.

2. Start the engine and allow it to reach normal operating temperature.

3. With the engine idling in neutral or park, gradually accelerate to about 2,000 rpm but not over 3,000 rpm.

4. Observe the EGR valve stem (Fig. 15-3). Visible movement of the stem should occur during this procedure. Movement can be determined by a change in the relative position of the groove on the stem.

5. Gradually permit the engine to return to idle. The valve stem should now move upward toward the closed position.

6. Repeat the process several times to confirm stem movement.

7. If the valve stem does not move, check the diaphragm for leaks as outlined later in this section.

8. If the diaphragm is satisfactory, check its vacuum source.

Testing the EGR Ported Vacuum Source

To check to make sure there is a ported vacuum at the EGR diaphragm nipple, do the following:

1. Disconnect the vacuum hose at the carburetor EGR port nipple, and attach a vacuum gauge to the supply port (Fig. 15-4).

2. Start the engine and allow it to reach its

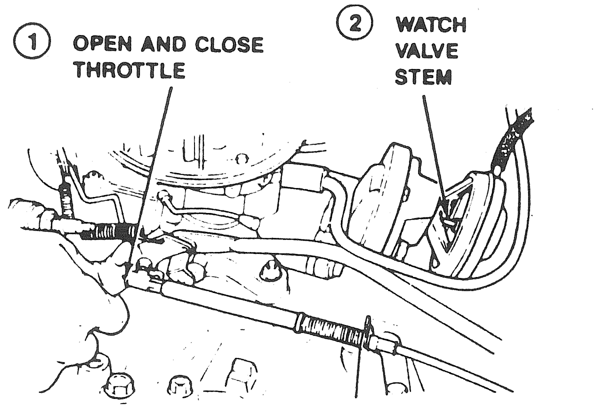


FIGURE 15-3
EGR valve operational check. (Courtesy of Ford Motor Co.)

normal operating temperature.

3. From idle, slowly accelerate the engine to about the half throttle position.

4. Note the reading on the vacuum gauge. It should begin to increase as the engine accelerates to half throttle; then it should start to decrease.

5. If there is no vacuum reading or it is very low, there is an obstruction in the carburetor EGR passage.

Checking the EGR Valve and Passages for Restrictions

If the EGR valve does not have a visible stem, this procedure can be used to check system serviceability. However, if the system passes this test, make sure there is a reliable vacuum signal to the EGR valve as outlined in the last procedure. This process also checks the EGR valve and passages on all systems for restrictions. To perform this check, do the following:

1. Disconnect and plug the EGR valve vacuum hose (Fig. 15-5).

2. Attach a vacuum pump hose to the EGR valve nipple.

3. Start the engine and allow it to reach normal operating temperature.

4. With the engine idling in neutral or park, slowly apply vacuum to the EGR valve until the pump gauge reads 15 inches.

5. Note the rpm on the tachometer. The idle speed should drop 150 rpm or more with the vacuum

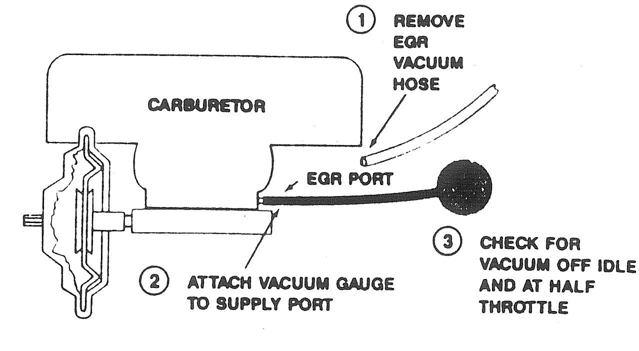


FIGURE 15-4
Testing for EGR valve source vacuum. (Courtesy of Ford Motor Co.)

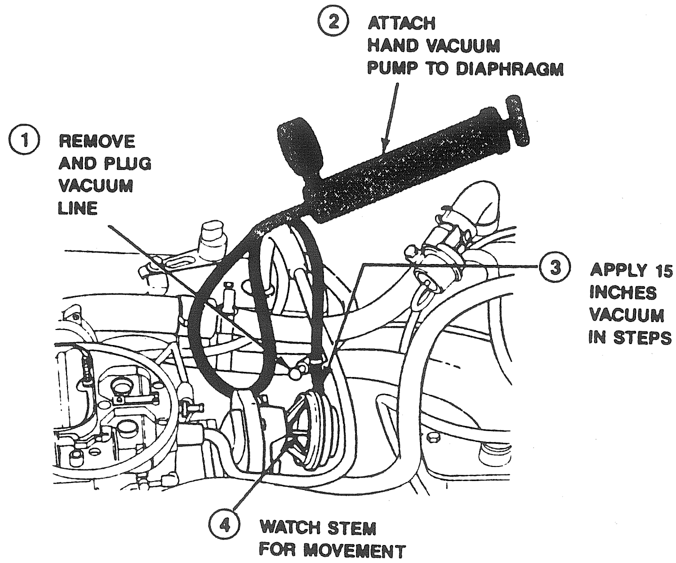


FIGURE 15-5
EGR flow test. (Courtesy of Ford Motor Co.)

signal applied. The engine may also idle rough or stall. The rpm drop and poor engine idle confirm that exhaust gas recirculation is taking place.

6. If the speed change does not occur or is less than the specified minimum, there are exhaust deposits within the EGR valve or intake manifold passages. Moreover, if the EGR has a visible stem that moves, but there is no change in engine idle, there is an exhaust gas restriction. In this situation, it is necessary to remove the EGR valve and inspect and clean its passage and those within the intake manifold.

7. If the stem of the EGR valve does not move, remove it for a bench test as outlined next.

8. Remove the tachometer from the engine.

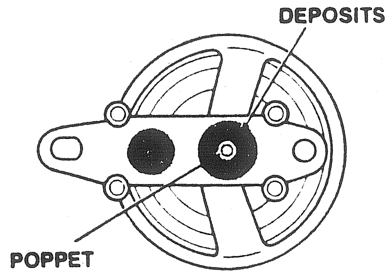


FIGURE 15-6
Deposits in the EGR valve ports. (Courtesy of Ford Motor Co.)

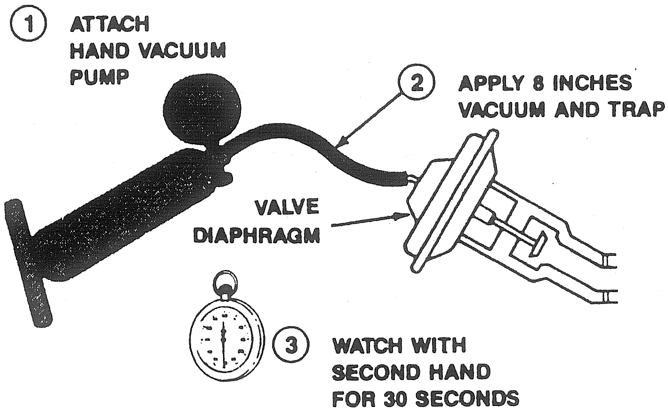


FIGURE 15-7
EGR valve diaphragm leak test. (Courtesy of Ford Motor Co.)

Bench Testing an EGR Valve

To check the EGR valve for deposit accumulation and serviceability, do the following:

1. Remove the EGR valve from the engine.

2. Inspect the valve, stem, and ports for deposits (Fig. 15-6). Black deposits are carbon and indicate a rich exhaust condition. In this case, check carburetion. Brown, beige, or gray deposits come from leaded gas. Advise the customer to use unleaded fuel if specified for the vehicle.

3. Attach the hose of a vacuum pump to the EGR valve nipple (Fig. 15-7).

4. Apply eight inches of vacuum to the diaphragm and trap it for at least 30 seconds.

5. Check the pump gauge reading. If the diaphragm still holds seven inches of vacuum, it is okay.

6. If the vacuum leaks down, the diaphragm is ruptured and the EGR assembly requires replacement.

7. Remove the vacuum pump hose from the EGR valve.

8. Using a new gasket, install the EGR valve onto the engine. Torque its mounting hardware to specifications.

Checking a Thermostatic Vacuum Switch

A common cause of losing the vacuum signal to the EGR valve is a defective vacuum switch. If the EGR system has a ported vacuum switch (PVS), check its serviceability by doing the following:

1. Remove both vacuum hoses from the switch (Fig. 15-8).

2. Connect a vacuum gauge hose to one PVS port and the test hose from a vacuum pump to the other.

3. With the pump, apply ten inches of vacuum to the switch.

4. Check the reading on the vacuum gauge attached to the other port. With the engine cold, there should be no reading. If there is a reading, the PVS is defective and requires replacement.

5. Operate the engine until its coolant warms up above PVS calibration temperature. The vacuum gauge should now read ten inches of vacuum. If it does not, the PVS is defective and requires replacement.

15-3 TESTING VENTURI VACUUM AND TIME DELAY SYSTEMS

If a system using either venturi vacuum or time delay does not have a signal to the EGR valve, you must perform a special test on the amplifier, reservoir, and delay relay.

Venturi Vacuum Amplifier Test

To check the venturi vacuum signal and the serviceability of the amplifier, do the following:

1. Run the engine until it reaches normal operating temperature. Stop the engine and install a tachometer.

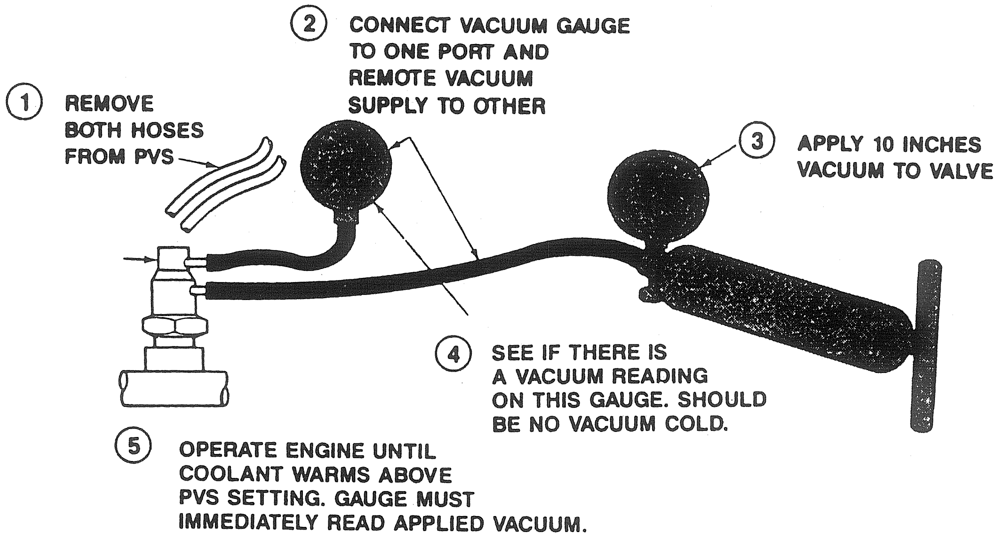


FIGURE 15-8
Testing a two-port PVS. (Courtesy of Ford Motor Co.)

2. Check all hoses and system components for condition, proper routing, and tight connections.

3. Disconnect the hose at the EGR valve (Fig. 15-9). Install a vacuum gauge into the open hose.

4. Disconnect the venturi vacuum hose at the carburetor.

5. Start the engine and check the reading on the amplifier gauge with the engine idling. It should be the setting specified for the particular amplifier used. If the amplifier requires a zero vacuum reading at idle, the reading can be no more than one-half inch of vacuum.

6. Watch the amplifier gauge as you accelerate the engine to 1,500 rpm to 2,000 rpm. The vacuum should not change with the venturi vacuum signal hose disconnected.

7. Return the engine to idle and reconnect the venturi vacuum hose at the carburetor nipple.

8. Check the amplifier vacuum gauge reading. If it increases more than one-half inch, check the curb idle against decal specifications.

9. Accelerate the engine to 1,500 rpm and back to idle speed. While doing so, check the vacuum gauge reading. The readings should now build to four inches or more during acceleration and return to zero vacuum or less than one-half inch at curb idle.

10. If the vacuum readings are not as specified, check the manifold vacuum. If the manifold

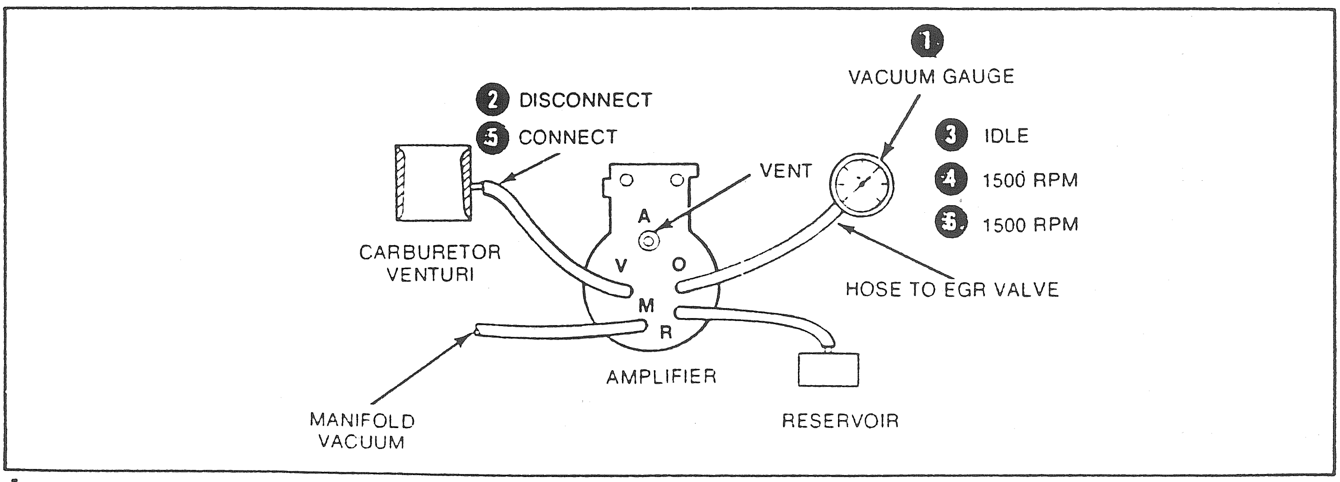


FIGURE 15-9
Checking a vacuum amplifier. (Courtesy of Ford Motor Co.)

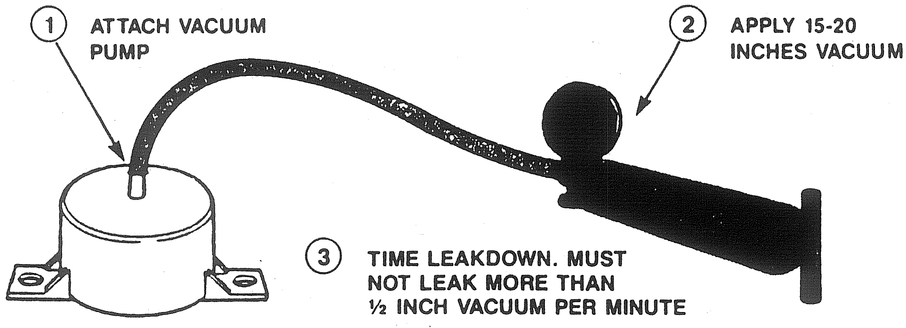


FIGURE 15-10
Testing a single-port vacuum reservoir. (Courtesy of Ford Motor Co.)

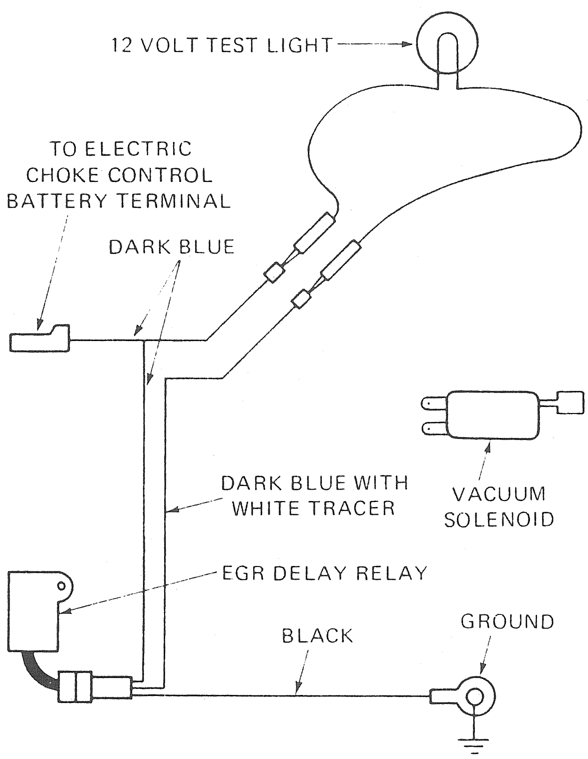


FIGURE 15-11
Checking the time delay relay.

vacuum is okay, check the reservoir as outlined in the next procedure. If it is satisfactory, replace the amplifier and repeat the test.

Vacuum Reservoir Check

To test the reservoir for leakage, do the following:

1. Remove the hose that connects to the reservoir from the amplifier.

2. Attach the hose from a vacuum pump to the reservoir nipple (Fig. 15-10).

3. Apply 15 inches to 20 inches of vacuum to the amplifier and trap.

4. Check the leakdown rate of the reservoir on the pump gauge. The leakdown rate should not exceed one-half inch of vacuum per minute. If it does, the reservoir is defective and requires replacement.

5. Reconnect the vacuum hose to the amplifier.

Time Delay Relay and Solenoid Check

If the amplifier system is functioning as outlined above and the EGR valve still does not have a vacuum signal, check the time delay relay and solenoid by doing the following:

1. Check the time delay system wiring for proper connections.

2. Remove the wiring connectors from the vacuum solenoid (Fig. 15-11).

3. Connect the leads of a test light to the disconnected solenoid wiring terminals.

4. Start the engine. The test light should burn for 35 seconds or the time specified by the manufacturer.

5. If the test light does not burn or turn off after the specified period, replace the time delay relay. If the light burns and then goes off as specified, proceed to Step 6.

6. Check all solenoid vacuum hoses and connections. Replace any cracked or leaking hoses.

7. Disconnect the wiring terminal to the solenoid. Using a jumper lead, ground one of the solenoid terminals.

8. Using a second jumper lead, connect the other solenoid terminal to the battery positive (+)

post. This should activate the solenoid vacuum valve, shutting off the signal to the EGR valve.

9. If the solenoid clicks when battery power is supplied, its electrical function is operating normally.

10. Plug in the wiring terminals to the solenoid.

11. Start the engine and let it idle for 35 seconds. Accelerate the engine to 2,000 rpm. If the EGR valve still does not operate, the vacuum valve within the solenoid is defective and the assembly must be replaced.

15-4 CHECKING COMPUTERIZED SYSTEM COMPONENTS

Although computerized EGR uses some of the same components as the basic early systems, a few parts are deleted and some are added. Therefore, when attempting to locate the cause of high or low EGR flow in a computerized system, *you will have to perform many of the same tests already described.*

However, since we are dealing with another type of control, namely the computer, and a few new components, there are also a number of tests for them. This section will describe how to check an EGR position sensor, how to check for EGR solenoid resistance, how to check for power in the EGR solenoid circuit, and how to check for EGR on/off control. *When testing a particular system, always refer to the appropriate service manual for the vehicle. Also, always use a digital voltmeter to perform the power and on/off circuit tests.*

EGR Position Sensor Check

To check the serviceability of a typical EGR position sensor, measure its resistance by doing the following:

1. With the engine shut off, disconnect the harness connector plug from the sensor.

2. Set the ohmmeter scale for a R × 1000 reading.

3. Connect one ohmmeter lead to the orange-white wire terminal.

4. Touch the other ohmmeter lead to the black-white wire terminal (Fig. 15-12).

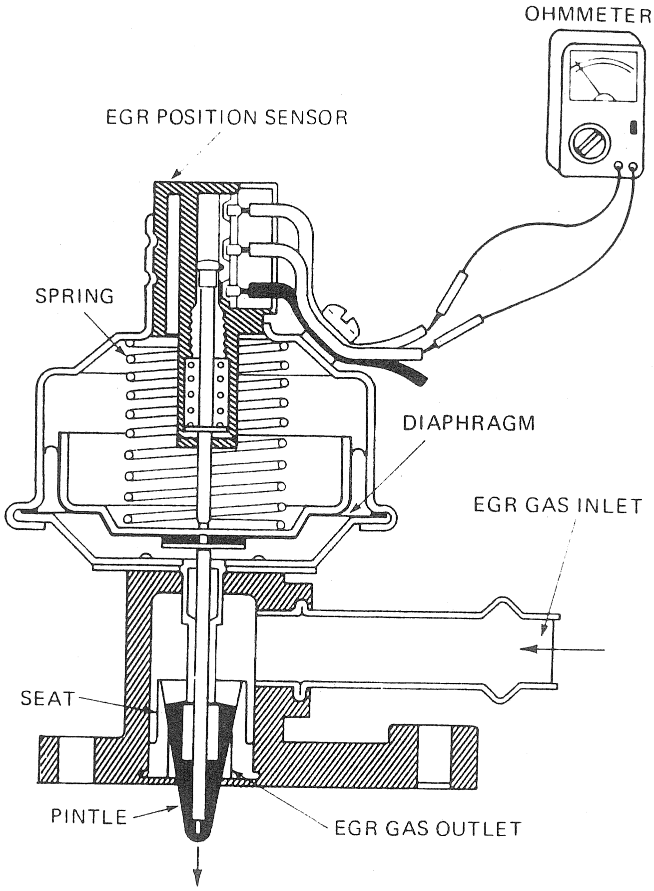


FIGURE 15-12
Testing the EGR valve position sensor.

5. Read the resistance on the meter. It should read 2,800 ohms to 5,300 ohms.

6. Set the ohmmeter scale for a R × 100 reading.

7. Move the lead from the black-white wire terminal to the one for the brown-light green wire.

8. Read the resistance on the meter. It should be 350 ohms to 940 ohms for this sensor.

9. If any of the readings are outside these limits, the sensor is defective, and the entire EGR valve requires replacement.

10. Plug in the EGR sensor harness connector.

EGR Solenoid Operational Test

To check the operation of the EGR solenoid arrangement shown in Fig. 15-13, do the following:

1. Disconnect the EGR hose from the solenoid.

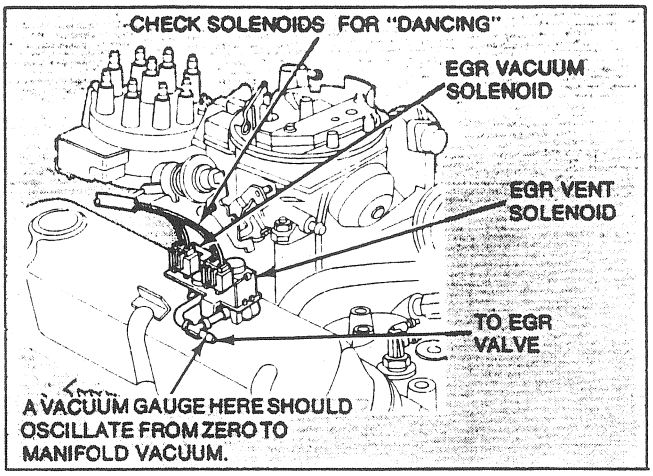


FIGURE 15-13
EGR solenoid inspection. (Courtesy of Ford Motor Co.)

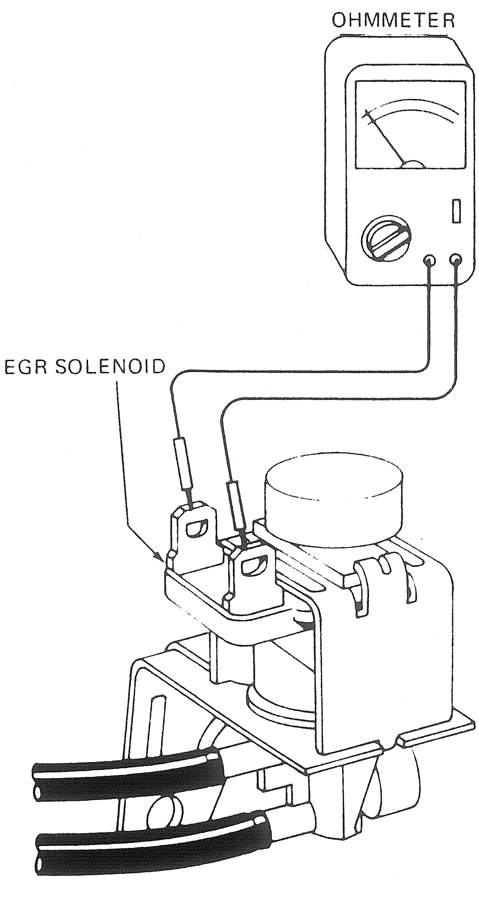


FIGURE 15-14
Checking solenoid resistance.

2. Connect the hose from a vacuum gauge to the solenoid nipple.

3. Following the manufacturer's instructions, connect a tachometer to the engine.

4. Start the engine and allow it to reach normal operating temperature.

5. Accelerate the engine to 1,500 rpm.

6. Check to see if the solenoids are dancing; that is, turning off and on.

7. Check the reading on the vacuum gauge. It should oscillate at any reading from zero to manifold vacuum.

8. If the solenoids do not dance or the gauge reading does not oscillate, proceed with the solenoid resistance tests.

9. Remove the vacuum gauge and tachometer. Plug the vacuum hose onto the solenoid nipple.

Solenoid Resistance Test

To test the serviceability of an EGR solenoid by measuring its resistance, do the following to test both the solenoids shown in Fig. 15-13:

1. Turn the ignition switch off and wait ten seconds.

2. Unplug the EGR solenoid terminal connectors.

3. Set the ohmmeter scale for a R × 10 reading.

4. Touch an ohmmeter lead to each of the solenoid terminals (Fig. 15-14).

5. Note the reading on the ohmmeter. The resistance should be 65 ohms to 110 ohms for each of these solenoids.

6. If the resistance is not to specifications, replace the defective solenoid and plug in all connectors.

7. If the reading on both solenoids is okay, proceed with the solenoid power check.

Solenoid Power Check

To test the availability of power to the EGR solenoid, do the following:

1. Turn the ignition switch off and wait ten

seconds.

2. Unplug the EGR solenoid terminal connectors.

3. Turn the ignition switch to the RUN position.

4. Connect the (−) voltmeter lead to a good ground (Fig. 15-15).

5. Touch the (+) voltmeter lead to the red V PWR lead terminal for both solenoids, one at a time.

6. Note the readings on the voltmeter.

7. Each reading should be 10.5 volts or greater.

8. If the readings are to specifications, proceed to the EGR on/off control test.

9. If the readings are not to specifications, check the harness connectors. If they are okay, use the pinpoint tests within the appropriate service manual to locate the cause of the low voltage readings.

10. Turn the ignition switch off and plug in the solenoid connectors.

EGR On/Off Control Test

To check the EGR solenoid control circuit to see if it is functioning properly, do the following:

1. Turn the ignition switch off and wait ten seconds.

2. Unplug the EGR solenoid terminal connectors.

3. Connect the (+) voltmeter lead to the red V PWR lead terminal for both solenoids, one at a time.

4. Touch the (−) voltmeter lead to the EGR output ground terminal for each solenoid (see Fig. 15-15).

5. Have an assistant turn the ignition switch to the RUN position. Depress and release the throttle pedal several times.

6. Observe the readings on the voltmeter. It should cycle between 0 volts and 10.5 volts or higher. This indicates the EGR control circuit is switching each solenoid on and off.

7. If a circuit does not switch on and off, use the pinpoint tests within the approporiate service manual to locate the cause of the problem.

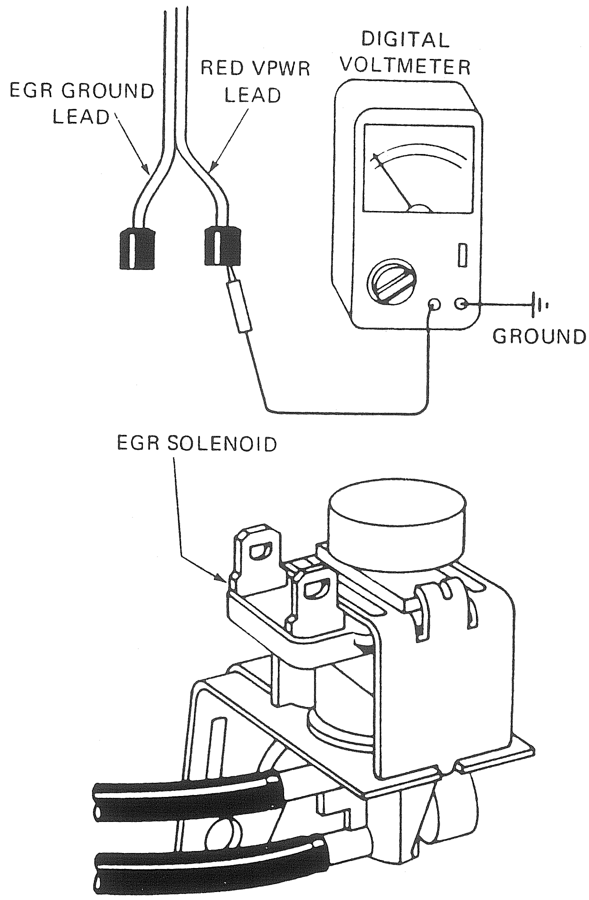


FIGURE 15-15
Testing for power to the solenoid.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. What special items must be tested if an exhaust gas recirculation (EGR) system is computer controlled [15-4]?
2. What is always the first step in troubleshooting an EGR system [15-1]?
3. Describe how to perform a time delay relay test [15-3].
4. Describe how to test a typical ported vacuum switch (PVS) [15-2].

REVIEW

1. How much voltage must there be to the EGR solenoids with the ignition key in the RUN position [15-4]?
   a. 2.5 volts
   b. 4.5 volts
   c. 6.5 volts
   d. 10.5 volts
2. What cleaning materials can be used to remove deposits from an EGR valve [15-1]?
   Technician A says an abrasive blast.
   Technician B states a manifold heat control valve solvent.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
3. How do you test an EGR valve position sensor [15-4]?
   Technician A states by measuring its resistance.
   Technician B replies by measuring the valve's flow rate.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
4. Technician A says manifold heat control valve solvent will not harm the EGR valve diaphragm.
   Technician B states manifold heat control valve solvent will ruin the EGR valve diaphragm.
   Who is correct [15-1]?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
5. If the gauge reading is one inch at the venturi vacuum amplifier at idle, what is the problem [15-3]?
   Technician A replies the curb idle speed is too high.
   Technician B says the amplifier is defective.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
6. What is the best method for checking EGR valve serviceability if the assembly does not have a visible stem [15-2]?
   Technician A says perform a flow test.
   Technician B states to check the valve's movement.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
7. If an EGR valve assembly will not hold a trapped vacuum, what is the most likely problem [15-2]?
   Technician A replies the check valve is defective.
   Technician B states the diaphragm is ruptured.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
8. A rich exhaust will cause deposits in the EGR valve that are [15-2]
   a. brown.
   b. gray.
   c. beige.
   d. black.

Chapter 16

TYPICAL COMPUTERIZED EVAPORATION AND EFE EMISSION CONTROL SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- explain the purpose of both the evaporation and early fuel evaporation (EFE) systems.
- identify and know the function of the components of an evaporation emissions control (EEC) system.
- describe the operation of a float bowl solenoid and purge solenoid valve.
- identify and know the purpose of the components of an EFE system.
- explain the operation of an EFE system.

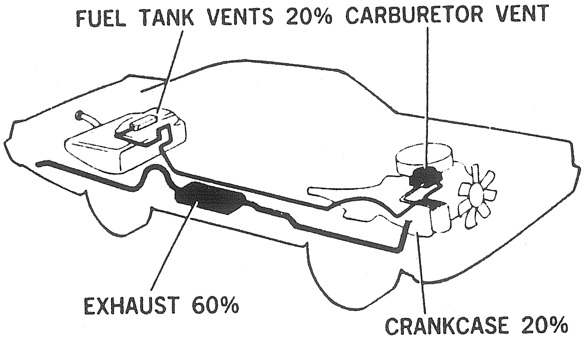


FIGURE 16-1
Sources of HC emissions from a typical automobile. (Courtesy of Chrysler Motors Corp.)

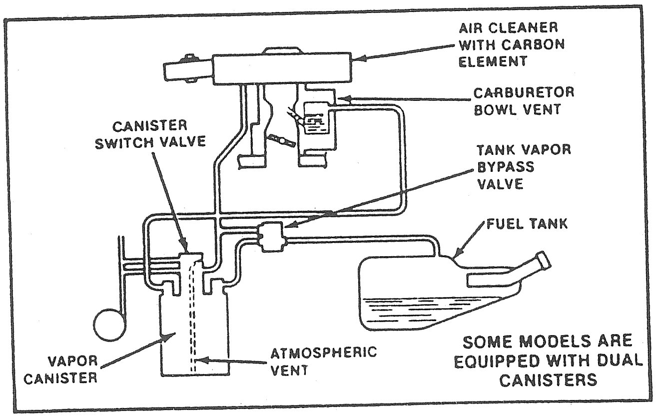


FIGURE 16-2
Typical EEC system. (Courtesy of Chrysler Motors Corp.)

Hydrocarbons (HC) were one of the first automotive exhaust emissions identified as harmful to life. Compounds of hydrogen and carbon, hydrocarbons, can be emitted from three different areas of the automobile (Fig. 16-1). For instance, about 60 percent of the average HC emissions come out as part of the exhaust gases. Another 20 percent enter the atmosphere from the engine's crankcase; while an additional 20 percent discharge from the fuel tank and carburetor vents.

By federal law, all manufacturers must install devices on automobiles and light trucks to control these hydrocarbon emissions to within safe limits. The first part of this chapter will describe a typical system used to control fuel tank and carburetor vent emissions. The second part explains a system used to reduce HC as well as carbon monoxide (CO) exhaust emissions during the engine warm-up period.

16-1 PURPOSE AND TYPES OF EVAPORATION EMISSIONS CONTROL SYSTEMS

Evaporation emissions control (EEC) systems first appeared in 1970 on all vehicles sold in California. However, federal requirements for the installation of the EEC system did not begin until 1971. Now, all vehicles, regardless of where they are sold, are required to have this system (Fig. 16-2).

The purpose of the EEC system is to reduce effectively the escape of hydrocarbon emissions into

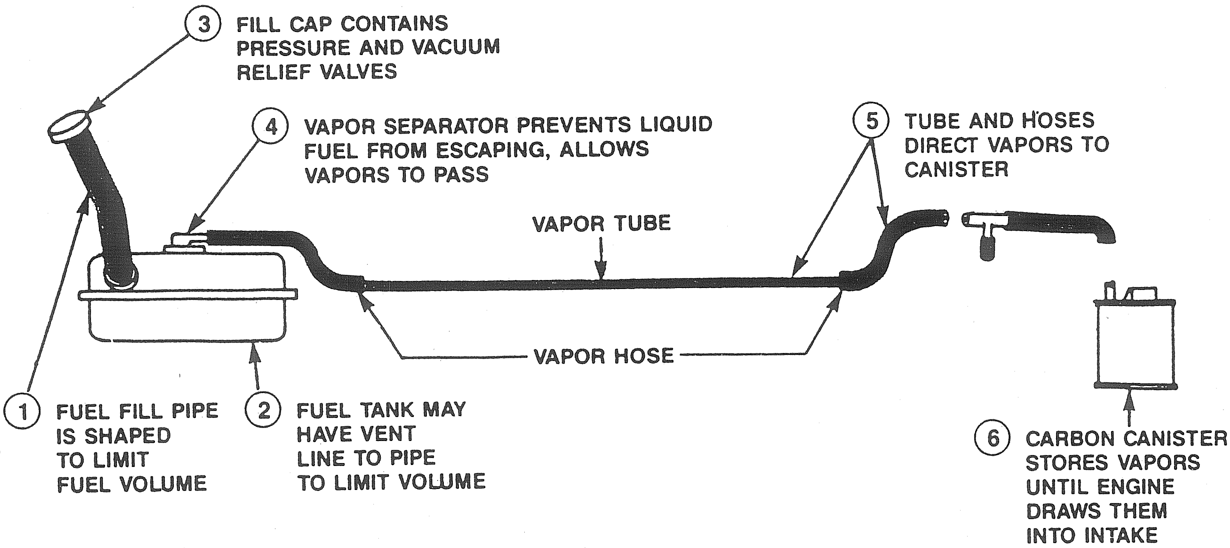


FIGURE 16-3
EEC system components. (Courtesy of Ford Motor Co.)

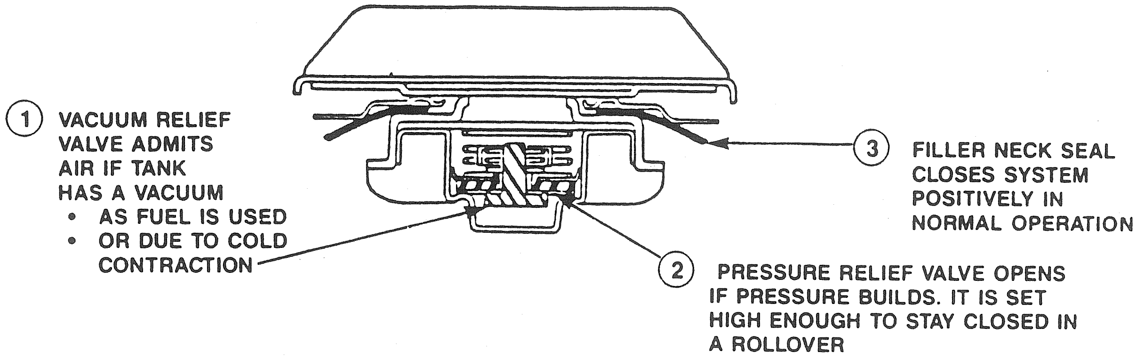


FIGURE 16-4
Design of the filler cap. (Courtesy of Ford Motor Co.)

the atmosphere from the vehicle fuel tank vent; from the carburetor float bowl vent; and, on some vehicles, from the throat of the carburetor and the intake manifold.

To perform this function, the EEC system traps and temporarily stores the HC vapors. The vapors are then purged from the storage area and directed into the engine for burning within the combustion chambers. HC emissions are reduced, and there is a slight increase in a vehicle's fuel economy.

Since 1970, automobile manufacturers have produced two basic types of EEC systems, one using crankcase storage and the other carbon canister storage. For instance, all 1970–1971 Chrysler vehicles and some Ford vehicles store the collected fuel vapors in the engine crankcase when the vehicle is not in operation. With the engine running, the vapors are then moved from the crankcase to the intake manifold via the positive crankcase ventilation (PCV) system.

Since 1972 all domestic automobiles have used the popular carbon canister as the storage device for fuel vapors. However, each vehicle manufacturer somewhat modifies the canister vapor storage and retrieval system to fit different vehicle configurations. For this reason, the next section presents only the components found in a typical system.

16-2 DESIGN OF A TYPICAL EEC SYSTEM

As mentioned, the various manufacturers use slightly different EEC system designs and control mechanisms on their vehicles to assure good vapor storage and purging. Further, the names of components that serve similar functions within the various systems may be different. In any case, a typical system will include a sealed filler cap, a fuel tank overfill limiting device, a liquid-vapor separator, a carbon canister (Fig. 16-3), and the carbon element.

Filler Cap

The fuel tank *filler cap* on an EEC-equipped vehicle is different from the one used on early vehicles that did not have the system. This cap prevents any normal liquid fuel spillage due to either gasoline surging within the tank or vehicle rollover. The cap also prevents the escape of fuel vapors into the atmosphere.

To perform these tasks, the filler cap incorporates a combination pressure and vacuum safety relief valve, a seal, and a two-stage locking mechanism (Fig. 16-4). The combination valve protects the tank from physical damage in the event of a system malfunction or a problem in a vent line that causes either excessive pressure or vacuum. Excessive pressure can develop within the tank due to heat expansion of its fuel volume. Vacuum, on the other hand, develops above the level of the fuel within the tank as a result of fuel pump action while the pump is transferring fuel to the carburetor. Neither of these problems will occur if the EEC system is functioning properly.

All caps will have a filler neck seal. This seal prevents any liquid or vapor leakage around the cap after it is secured in place.

Most EEC filler caps also have some form of two-stage locking mechanism. This usually consists of two pairs of tangs arranged like those on a radiator cap. These tangs permit partial loosening of the cap in order to break the cap-to-tank seal and relieve pressure without completely separating the cap from the filler neck. To remove the cap, at least another 90-degree turn of the unit is necessary. This action prevents tank pressure from forcing liquid fuel out of the tank if someone removes the cap too quickly.

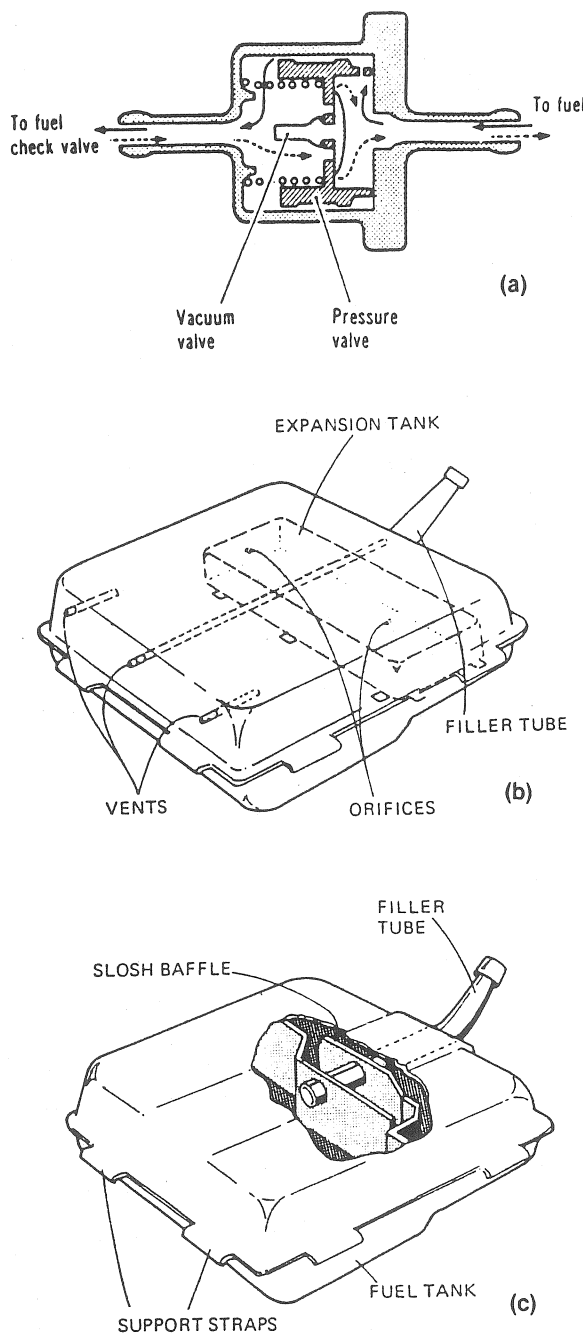


FIGURE 16-5
Types of overfill limiting devices.

One final important fact you should remember. If an EEC cap needs replacement, *always use an exact duplicate.* For instance, never install a cap without a pressure-vacuum valve into a system that requires one. If this is done, the fuel tank may sustain damage due to pressure from fuel expansion or due to a vacuum from fuel pump action.

Overfill Limiting Device

An EEC system has some type of *overfill limiting device* (Fig. 16-5). This component stops the normal complete filling of the fuel tank and thus provides an internal expansion space into which liquid fuel or vapors can safely expand on a hot day. This space amounts to about 10 percent to 12 percent of the total capacity of the tank.

The three types of limiting devices in use are (1) a two-way valve, (2) an expansion tank, and (3) a specially designed filler tube. The two-way limiting valve (Fig. 16-5a) may be within or on the carbon canister or in the vapor line between this unit and the fuel tank.

In either case, the valve serves three functions. First, the overfill-limiting portion of the valve prevents overfilling the tank. This is accomplished by allowing only a small amount of vapor pressure, caused by the rising fuel level in the tank during the refueling process, to pass through an orifice to the canister. This action forces the fuel to back up in the filler tube before the tank is actually full. Consequently, the service nozzle automatically shuts off.

The second and third functions of this limiter device are to act as a combination pressure and vacuum relief valve, like the one found in the filler cap. In other words, when the EEC system has a two-way valve, the filler cap does not need or have an integral pressure and vacuum valve.

The second type of overfill limiting device is in the form of a small *expansion tank* mounted on the inside upper surface of the fuel tank (Fig. 16-5b). This small tank takes up around one-tenth of the main tank's original volume, or about the space of two gallons of fuel.

The expansion tank has a series of small holes machined into it. The size of these openings is such that it would normally require about 10 to 15 minutes to fill the expansion tank with gasoline during the refueling process. As a result, there remains approximately a two-gallon free space above the level of the fuel in the main tank when the gauge reads full. This area takes care of any fuel or vapor expansion within the main tank in the event the vehicle sits in the sun for a prolonged period. It also serves as a vapor collection area for the EEC system.

A number of manufacturers install the fuel filler tube in such a way that it acts as an overfill limiting device (Fig. 16-5c). In this case, the filler tube extends a given distance below the top of the tank, thus preventing it from being filled 100 percent. This action provides an adequate space at the top to permit room for fuel and vapor expansion.

Liquid-Vapor Separators

The EEC system must have some form of *liquid-vapor separator.* This component prevents any liquid gasoline from reaching the carbon canister, which would quickly overload its normal capacity. There are three common kinds of separators: (1) the open-cell foam, (2) the standpipe, and (3) the float. Figure 16-6a shows a foam-type, liquid-vapor separator. This device usually mounts at the top center of the tank. In this location, the internal expansion area of the tank provides an adequate breathing space for the separator.

The separator itself consists of a quantity of open-cell foam that is inside a small housing with two openings. The opening at the bottom of the housing permits the entrance of fuel vapors from the tank's expansion area. The top opening has an orifice and fitting that connect via a vapor hose and line to the storage canister.

With this device, only fuel vapors pass through the foam as they move from the tank, through the orifice, and into the line to the canister. Liquid droplets of gasoline cannot pass through the foam material and, therefore, cannot enter the canister. Instead, the liquid just returns to the fuel tank.

Figure 16-5b illustrates the standpipe separator. This unit fits above the fuel tank in a vertical or horizontal position and has a number of lines of different lengths running to each corner, as shown. The separator has a vent line to the storage area of the canister that attaches to the highest standpipe. This vent, in some cases, may also have an orifice to minimize the possibility of liquid fuel transfer to the canister.

The multiple lines within the separator and tank serve two purposes. First, they constantly act as vents for the tank as the engine consumes fuel. Second, at least one of the lines provides a liquid drain-back into the tank of any fuel droplets that accumulate within the separator.

Any time fuel vapors condense in the separator from the standpipes, the resulting liquid drains back into the tank via the shortest standpipe or through a drain opening in one of the other vent lines. In addition, if a vehicle with a standpipe separator is parked on an incline, any fuel collected that does not immediately drain back into the tank remains in the unit until the vehicle operates once again on a level road. As a result, this separator acts as a baffle to stop fuel from ever entering the canister regardless of the amount of vapor condensation or vehicle attitude.

Figure 16-7 illustrates the float separator. On some vehicles, this device is built into the tank, while on others it mounts directly on top of it. Regardless, the unit basically consists of a spring-loaded sealed float that operates inside a housing with two openings. The lower opening permits the entrance of fuel or vapors into the housing below the float, and provides a passage for any accumulated liquid to drain off back out and into the tank. The second upper opening has an orifice and fitting that connect to a vent hose and line leading to the canister.

The float is a sealed unit that is maintained in its upward position by action of the spring and liquid fuel in the housing. On the upper end of the float is a pointed valve that contacts a seat, indexing over the orificed outlet opening.

If fuel accumulates in the housing, the buoyancy of the float and spring tension maintain the valve in the closed position. In this case, neither fuel vapors nor liquid fuel can transfer to the canister. This also prevents an external fuel leak at the canister if the vehicle were to turn over.

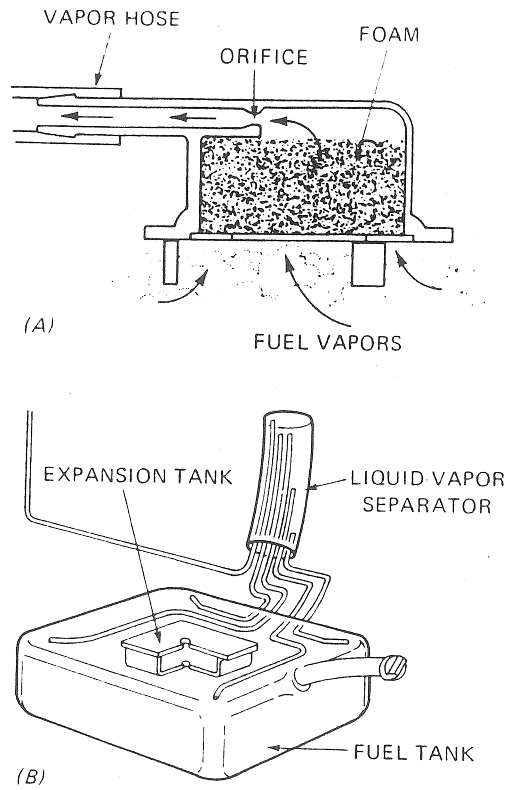


FIGURE 16-6
Foam and standpipe liquid-vapor separators.

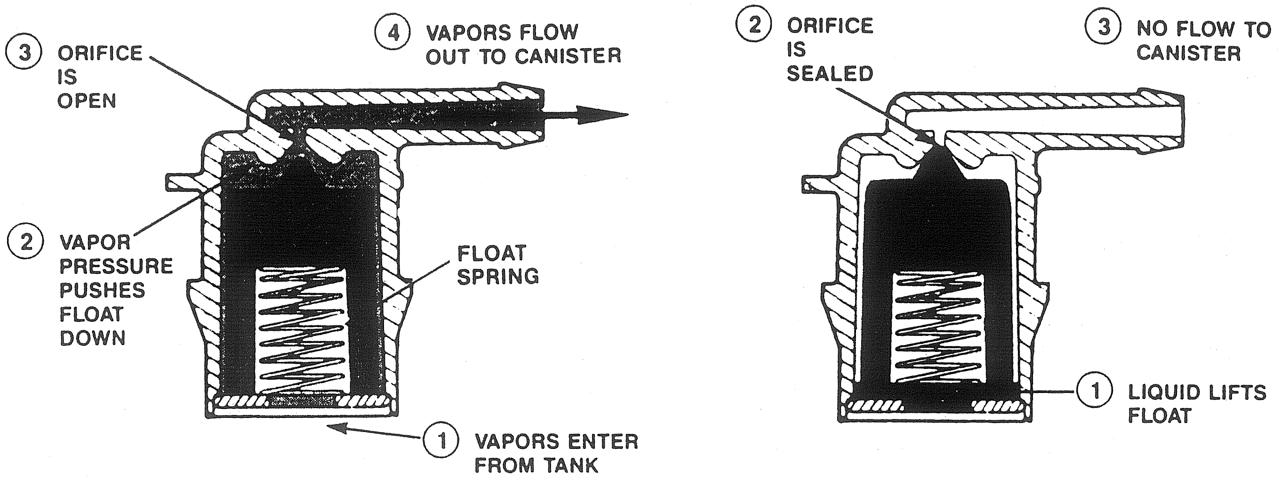


FIGURE 16-7
Float-type, liquid-vapor separator. (Courtesy of Ford Motor Co.)

If vapor pressure builds up in the housing, it will push the float down against spring tension and open the vapor passage. Fuel vapors can now transfer via the orifice and line to the canister.

Carbon Canister

The *carbon canister* serves as the storage place for fuel tank and carburetor vapors (Fig. 16-8). This metal or plastic canister is mounted either under the hood or in a fender well and holds a given quantity of activated carbon (charcoal) granules. These store up to one-third of their weight in fuel vapors.

A typical canister holds 300 grams to 625 grams of carbon. Each gram has a surface area of 1,100 square meters or more than a quarter of a mile. As a result, the exposed surface area of the carbon in a canister can store about a cup of liquid fuel in vapor form.

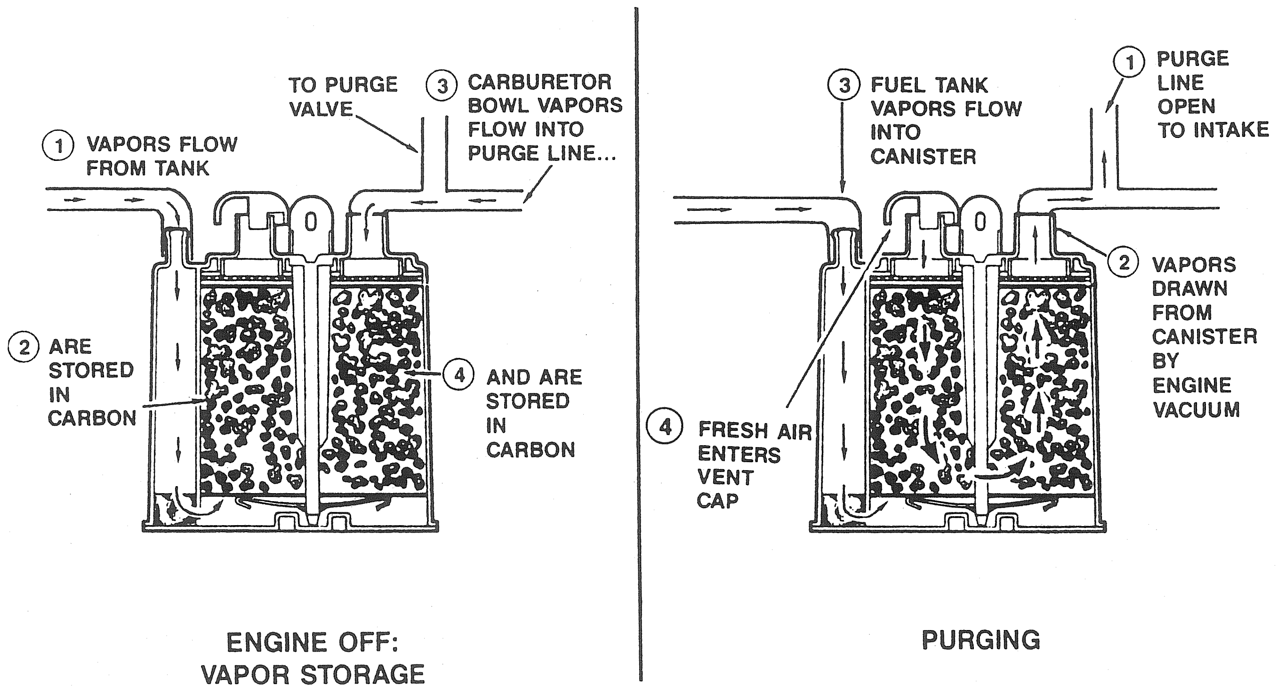


FIGURE 16-8
Typical canister design and operation. (Courtesy of Ford Motor Co.)

Fuel vapor molecules attach themselves very easily to the surface area of the carbon by absorption. Therefore, the carbon forms a good vapor trap. However, the attracting force between the vapors and carbon is not very strong. Consequently, any fresh air entering the canister can easily remove the vapor molecules from the granules. For example, the left diagram of Fig. 16-8 shows how the carbon stores the vapors from the fuel tank and carburetor. The right-hand diagram illustrates how engine vacuum pulls fresh air into the canister to purge the vapors from the granules and route them to the intake manifold.

Some canisters have an integral air filter. This unit may be an oiled foam or fiberglass filtering element. In either case, the device prevents dust or other contaminants from entering the canister with the purge air.

Some EEC systems require more than one canister. Two canisters are necessary, for instance, if the vehicle has a large capacity fuel tank, dual fuel tanks, or dual carburetor float bowls.

Carbon Element

A *carbon element* is a device that fits inside the standard air cleaner element, between it and the carburetor throat (Fig. 16-9). The element temporarily stores fuel vapors remaining in the carburetor throat and intake manifold after the engine is shut down. Before the addition of the carbon element, these vapors could escape out of the carburetor throat and enter the atmosphere through the air cleaner snorkel. However, when the engine is restarted, the air passing through the filter and carbon element purges these vapors and carries them back through the carburetor, intake manifold, and into the combustion chambers.

EEC System Operation

During the heat soak period when the engine is not running, fuel vapors that collect in the space above the fuel in the tank pass through the liquid vapor separator to the carbon canister. At the same time, any vapors above the level of the fuel in the carburetor float bowl also move into the canister. All collected vapors are absorbed into the carbon granules (see Fig. 16-8). Any remaining fuel vapors in the throat of the carburetor and intake manifold cannot pass into the canister. Instead, they are absorbed

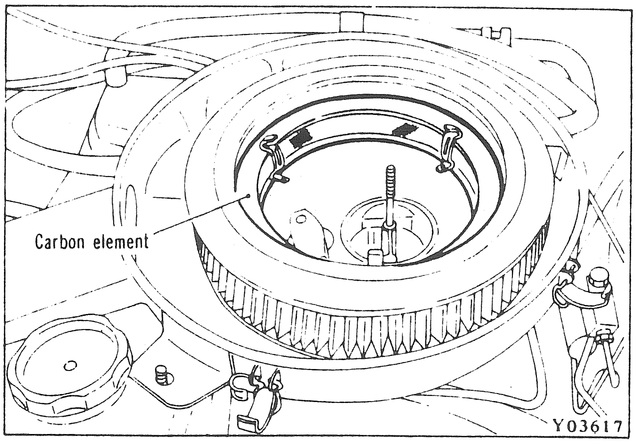


FIGURE 16-9
Carbon element. (Courtesy of Chrysler Motors Corp.)

into the carbon element within the air cleaner housing.

When the driver starts the engine, purge air enters the canister through its filtering element. The air removes the fuel vapor molecules from the carbon granules and carries them either into the intake manifold or air cleaner. From either of these locations, the vapors mix with the air/fuel charge on its way to the combustion chambers.

16-3 CARBURETOR FLOAT BOWL VENT CONTROLS

In early EEC systems, the control of carburetor venting was accomplished through either a mechanical or electrical/pneumatic valve. These valves normally opened the vent line between the float bowl and the canister when the engine was off during the heat soak period.

With the mechanical-type valve, the vent would close at any throttle position above idle. The electrical/pneumatic valve closed the carburetor vent any time the ignition switch was on and there was high intake manifold vacuum, such as at idle.

Fuel Bowl Solenoid Valve

Many contemporary systems now just use an electrical *fuel bowl solenoid valve* (Fig. 16-10). This device contains a valve that is spring-loaded open and closed by the action of the solenoid. The solenoid valve is installed in the vapor line between the float bowl and the canister.

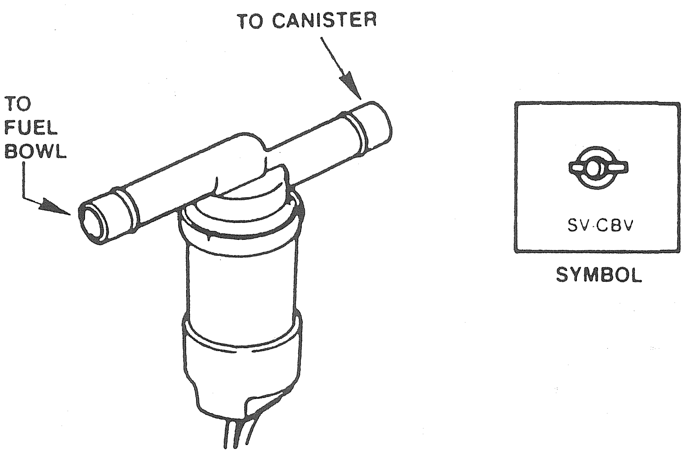


FIGURE 16-10
Fuel bowl solenoid valve. (Courtesy of Ford Motor Co.)

Solenoid Operation

There are only two stages of operation for the solenoid, open and closed (Fig. 16-11). When the ignition switch is shut off, electrical power is cut off to the solenoid. With the solenoid de-energized, the spring pushes the plunger up, unseating the attached valve. As a result, float bowl vapors can flow freely to the canister.

As the driver turns the ignition switch on to start the engine, the solenoid is energized. The resulting magnetic field pulls the plunger down, seating the valve. At this time, float bowl vapors are blocked at the valve seat and cannot flow to the canister.

16-4 COMPUTERIZED CANISTER PURGE CONTROL

Before the advent of computerized engine control systems, a number of different methods were used to control canister purging. A few rather simple ways consisted of just connecting a purge hose from the canister to the air cleaner or to a ported vacuum fitting on the carburetor. Other methods incorporated the use of some form of vacuum-operated purge valve that could vary the amount of canister purging under various driving conditions.

None of these devices provided very precise control of canister purging because they could only respond to a single input in the form of a vacuum signal. As engine control systems became computerized in order to further curb harmful emissions, pro-

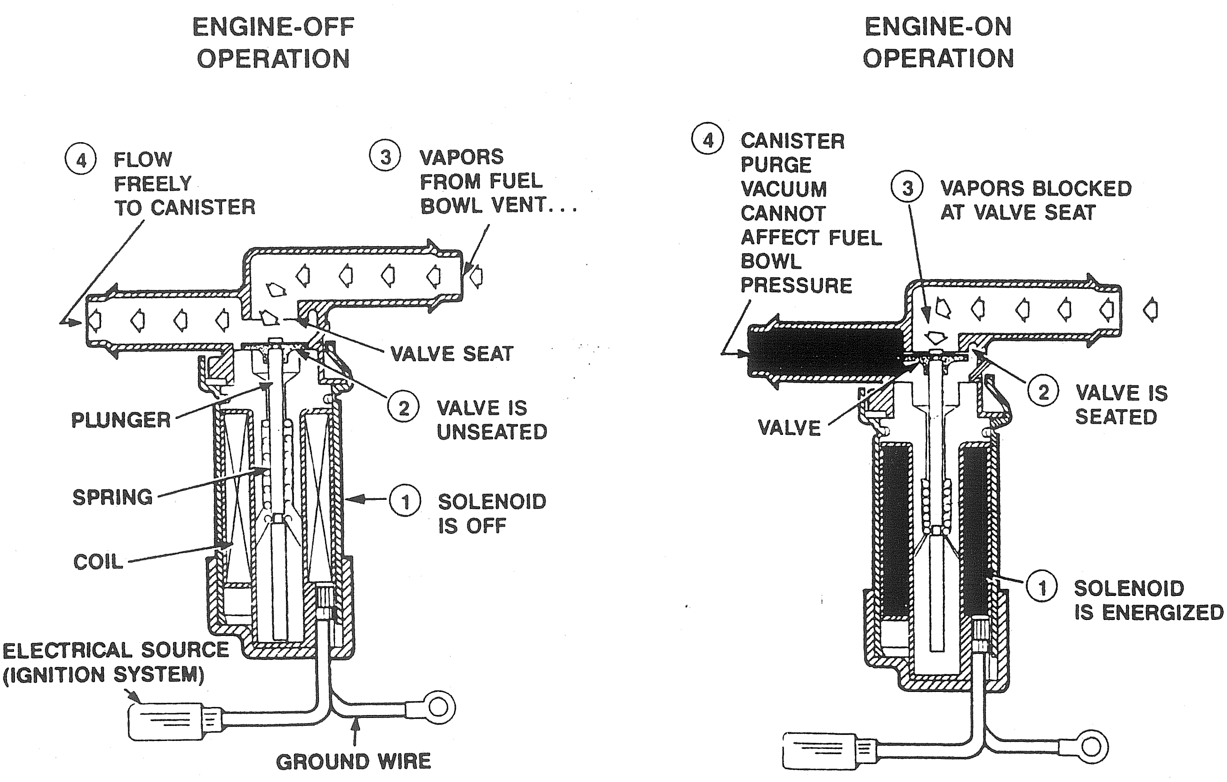


FIGURE 16-11
Bowl solenoid operation. (Courtesy of Ford Motor Co.)

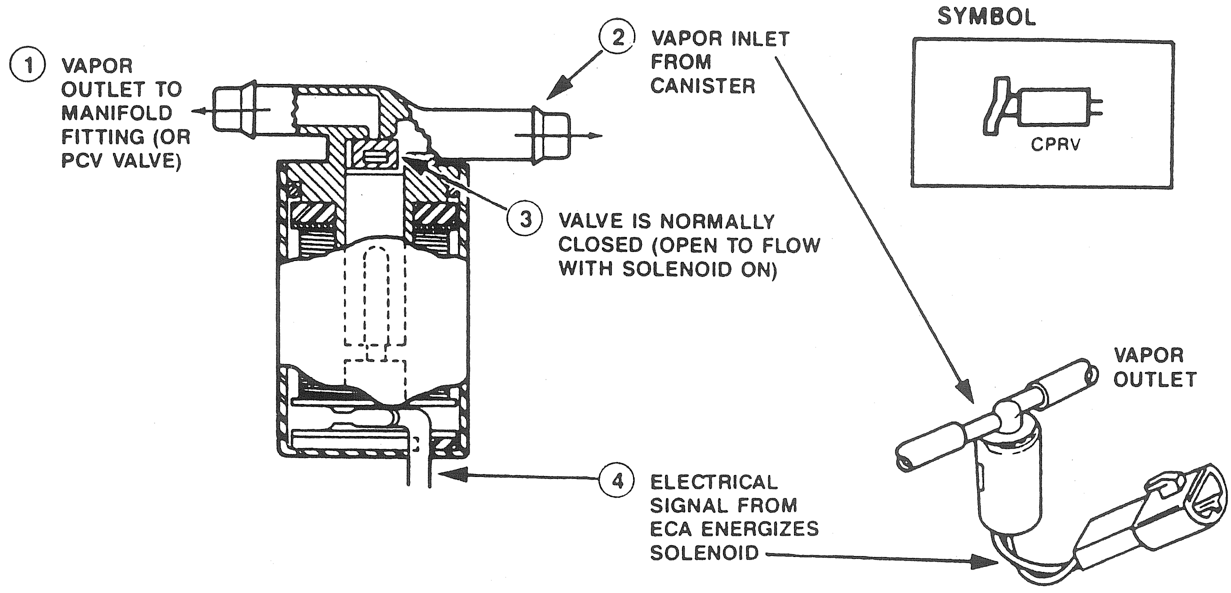


FIGURE 16–12
Canister purge solenoid. (Courtesy of Ford Motor Co.)

vide increased fuel economy, and improve driveability, this portion of the EEC system came under microcomputer control.

Canister Purge Solenoid

The component of the EEC system that is under the control of the microcomputer is the *canister purge solenoid* (Fig. 16–12). The solenoid is located in the line between the intake manifold and the carbon canister. Its function is to control the flow of fuel vapors from the canister to the intake manifold during the various phases of engine operation.

The solenoid contains a vacuum valve that is normally closed. The valve is opened by the solenoid when it is energized by a microcomputer called the electronic control assembly (ECA). The ECA performs this function by providing a ground circuit for the solenoid.

Purge Solenoid Operation

When the ECA provides the ground circuit for the solenoid, its internal purge valve opens (Fig. 16–13). As a result, fresh air enters the canister and removes the fuel vapors from the carbon. The collected vapors then pass through a restrictor that limits the flow rate to prevent flooding before moving into the intake manifold.

The actual on and off times of the purge solenoid are programmed into the ECA. The ECA will activate the solenoid when the following typical conditions are met:

- The engine coolant temperature is greater than a cold engine value and less than an overheat value.
- The engine rpm is above a specified value.
- A given period of time has passed since engine start-up.
- The engine is not operating at closed throttle.

16-5 NEED FOR THE EFE SYSTEM

Gasoline engines have always needed some form of *early fuel evaporation (EFE) system.* This system promotes gasoline vaporization after a cold engine is started and is running at below its normal operating temperature. *Vaporization* is the act of changing a liquid, such as gasoline, into a gas, and this change of state only occurs when the liquid absorbs enough heat to boil. The factors that affect fuel vaporization are outside air temperature, fuel temperature, intake manifold temperature, and manifold vacuum.

A vaporized air/fuel mixture is necesary for good driveability, engine power, and reduced HC and CO emissions. Without vaporizing the air/fuel mixture, it is impossible to distribute the charge in equal quantities to all the combustion chambers.

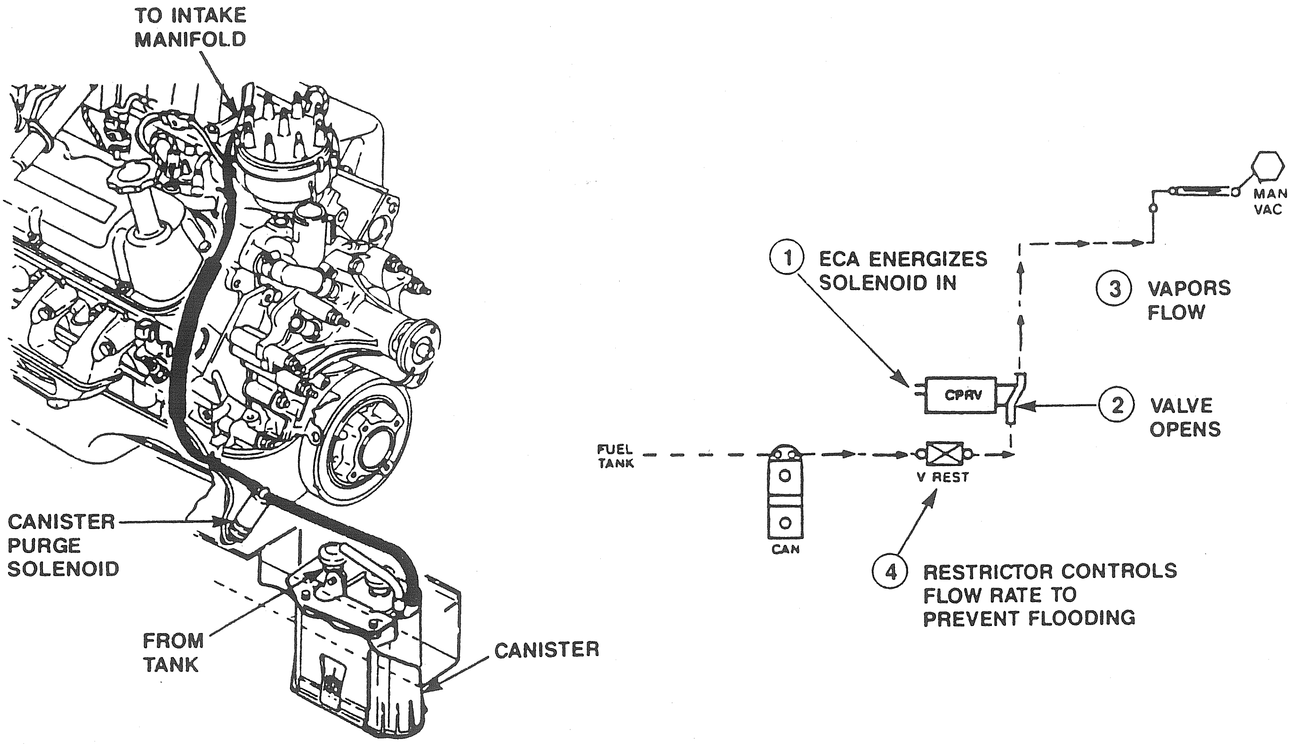


FIGURE 16-13
Purge solenoid installation and operation. (Courtesy of Ford Motor Co.)

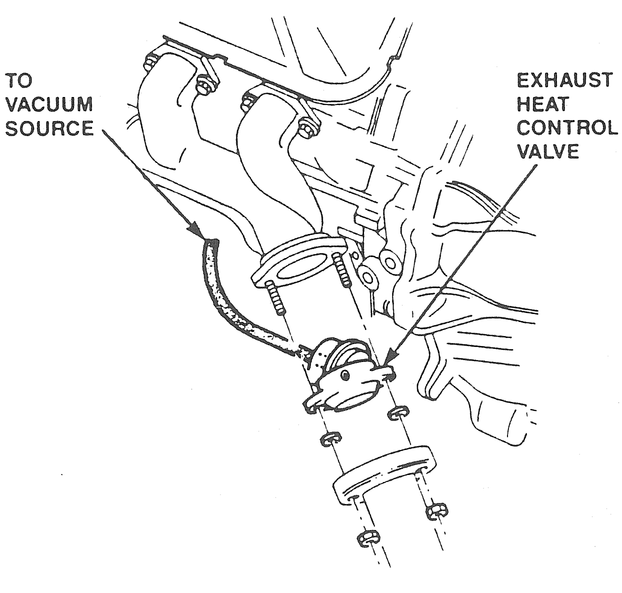


FIGURE 16-14
Heat control valve installation. (Courtesy of Ford Motor Co.)

The reason for this is that a gaseous air/fuel charge travels much more easily around the branch corners in the intake manifold. On the other hand, liquid particles, being relatively heavy, tend to drop out or continue in one direction and collide with the walls of the manifold or just move on to another cylinder. This results in unequal fuel distribution to the combustion chamber and the need to overchoke an engine.

The choke restricts the air flow through the carburetor to the intake manifold, thereby enriching the air/fuel mixture. The enriched mixture is necessary so that the total resultant charge reaching the cylinders will contain sufficient vaporized material to cause combustion. Although a slightly enriched mixture is necessary for good cold engine start-up, it does create higher CO and HC emissions, driveability problems, and poor fuel economy.

By heating the air/fuel charge, the EFE system reduces the length of time the engine has to be choked, thus promoting vaporization. This heating process takes place either within the intake manifold or at the base of the carburetor.

16-6 DESIGN AND OPERATION OF EFE SYSTEMS

There are two basic types of EFE systems. The first system uses a *manifold heat control valve* (Fig. 16-14). This valve routes exhaust gases through a crossover passage to warm the intake manifold when the engine is cold. As a result, the manifold itself heats the contained air/fuel mixture to improve its vaporization.

Vacuum-Operated Valve

The assembly consists of a rotating valve that is operated by a vacuum motor. The valve itself turns on a shaft mounted inside a cast-iron body that fits between the exhaust manifold outlet and the exhaust pipe. Linked to the shaft that extends through the cast-iron body is a diaphragm with a vacuum motor. This diaphragm activates the shaft and valve by reacting to a vacuum signal supplied by the intake manifold (Fig. 16-15). A ported vacuum switch (PVS), a solenoid-operated vacuum valve, or both control the signal to the motor.

Valve and PVS Operation

Figure 16-15 also illustrates control valve operation. In the upper diagram, cold engine coolant keeps the PVS open. This allows engine vacuum to be applied to the diaphragm, which pulls down on the lever to close the valve. With the valve closed, the exhaust gases are blocked and must divert back through the crossover passage in the intake manifold. The exhaust gas flow heats the manifold.

When the engine coolant temperature reaches a given value, the PVS closes to block the manifold vacuum to the motor (lower diagram of Fig. 16-15). By this time, the engine has developed enough heat that the intake manifold remains warm due to radiation. With the vacuum signal cut off, a spring beneath the diaphragm moves it upward, opening the valve. The spent gases can now flow directly into the exhaust system. Lastly, the valve will open any time there is a sufficient loss of engine vacuum due to either opening the throttle for acceleration or shutting the engine off.

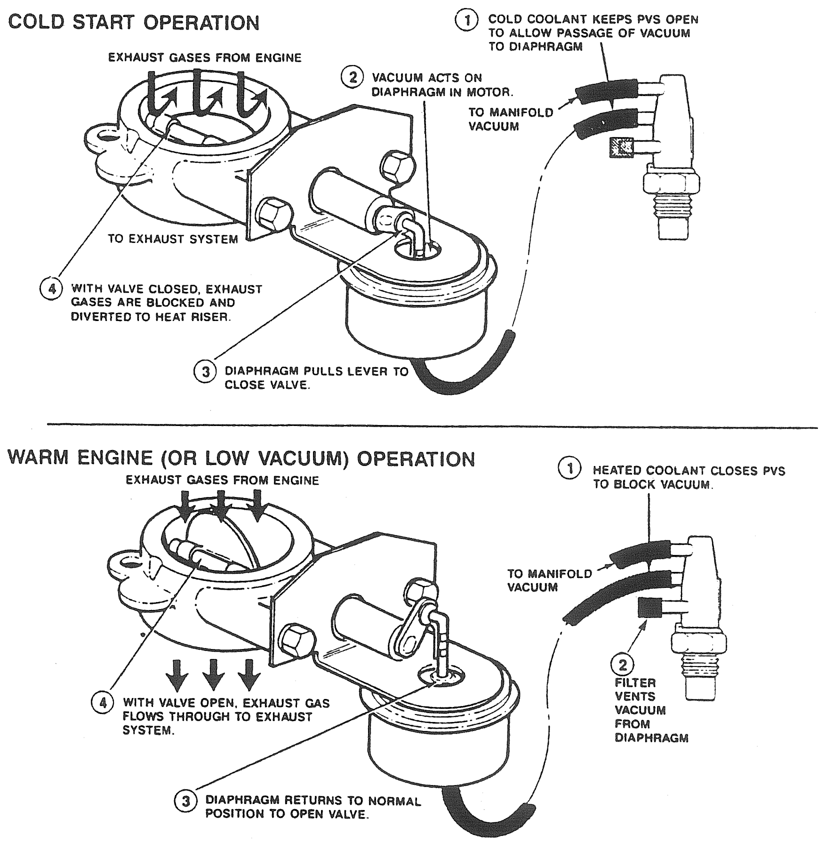
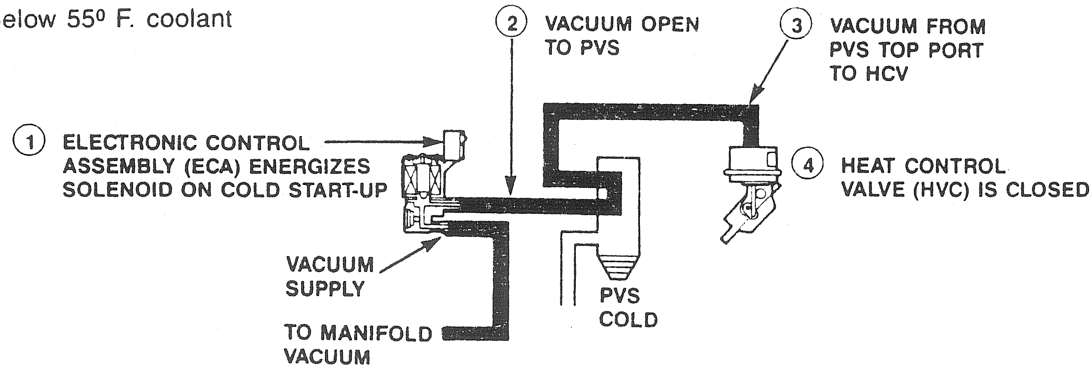


FIGURE 16-15
Heat control valve operation. (Courtesy of Ford Motor Co.)

HOW THE ELECTRONIC CONTROL VACUUM SYSTEM WORKS

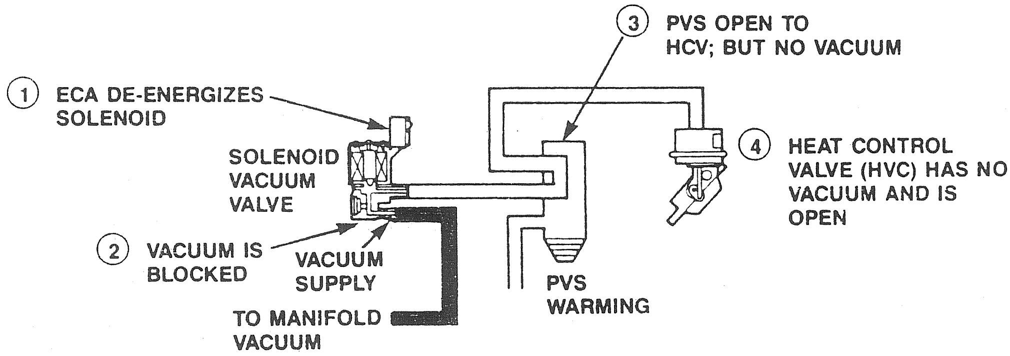
COLD ENGINE

- Below 55° F. coolant



WARM ENGINE

- Coolant temperature above 100° F.



HOT ENGINE

- Coolant temperature above 160° F.
- Vacuum switched by warm PVS

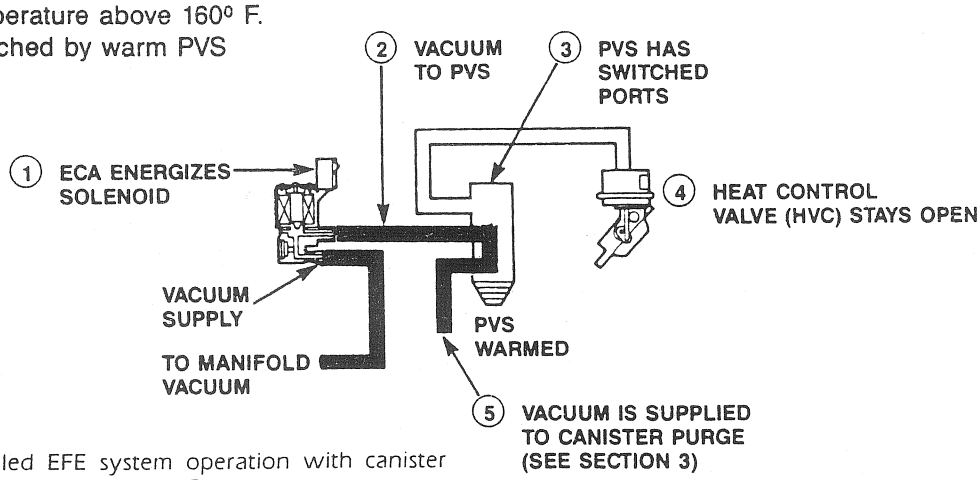


FIGURE 16-16
Computer-controlled EFE system operation with canister purging. (Courtesy of Ford Motor Co.)

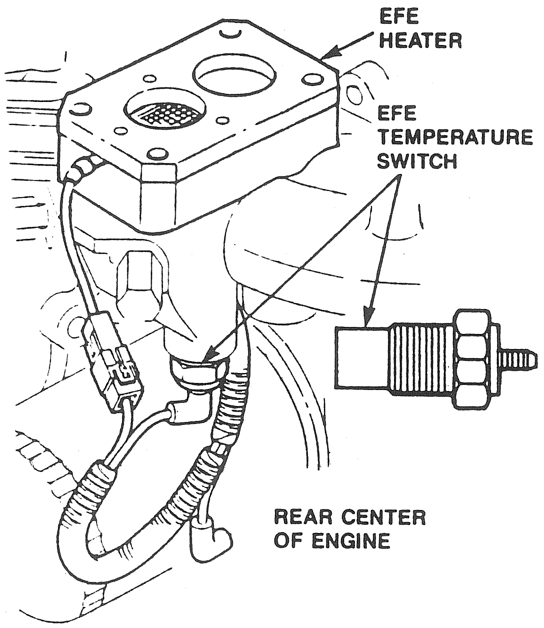


FIGURE 16-17
Heater and temperature switch. (Courtesy of Ford Motor Co.)

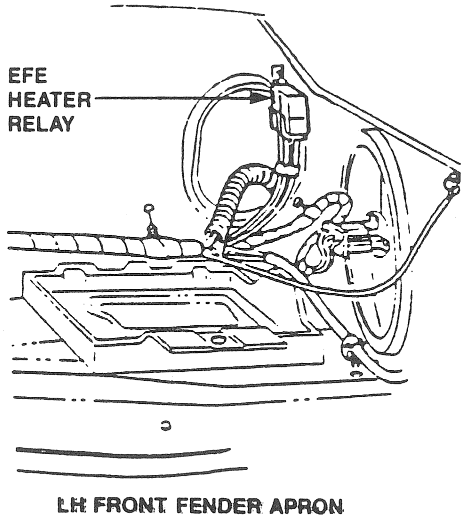


FIGURE 16-18
Heater relay. (Courtesy of Ford Motor Co.)

Microcomputer-Controlled Heat Control Valve System

In some engine control systems, a solenoid-operated valve and a PVS precisely regulate the operation of both the heat control valve and canister purging (Fig. 16-16). In this system, the solenoid vacuum valve controls the vacuum signal between the intake manifold and the PVS. The PVS, in turn, directs the vacuum signal to either the control valve or the canister.

When the engine is cold, the ECA provides a ground circuit for the solenoid, and it energizes. This opens the valve and permits a vacuum signal to pass to the PVS. Since the PVS is also open, the signal can act on the heat control valve to close it.

As engine temperature reaches a set value—in the example, 100°F—the ECA de-energizes the solenoid. However, the PVS remains open. In this situation, the solenoid valve is now closed, cutting off the vacuum signal to the PVS and the control valve. As a result, the diaphragm spring opens the control valve.

At a higher specified coolant temperature, the ECA again energizes the solenoid, and the PVS closes the control valve port and opens the canister port. As a result, intake manifold vacuum is supplied to the canister purge line, and the heat control valve remains open due to spring action.

EFE Heater System

The second EFE system consists of a heater, temperature switch, and a relay. The *heater grid* is a resistance element that fits between the base of the carburetor and the intake manifold (Fig. 16-17). Its function is to heat the air/fuel mixture leaving the carburetor before it enters the intake manifold to improve vaporization. The heater functions for a few minutes until intake manifold temperature reaches a pre-set value by radiation. This permits a leaner choke setting for lower emission levels without cold driveability problems.

The *temperature switch* controls the operation of the heater. The switch, in the example, mounts on the bottom of the intake manifold near its center. The switch closes the heater circuit any time manifold temperature is less than 128°F.

The *heater relay* (Fig. 16-18) provides the power source for the heater. When the temperature switch is closed, it grounds the relay coil. The magnetism created by the now energized coil, in turn, closes the relay contacts and electrical power is sent to the heater grid.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. Briefly describe the two EFE systems [16-6].
2. An EEC system reduces HC emissions from which areas of an automobile [16-1]?
3. Explain why an EFE system is needed [16-5].
4. Why does an EEC filler cap have a two-stage locking mechanism [16-2]?
5. Describe the early types of carburetor vent valves used on an EEC system [16-3].
6. What are the factors that determine when a purge control valve solenoid will open [16-4]?

REVIEW

1. On a computerized EFE system, when does the ECA energize the solenoid [16-6]?
   a. at a hot temperature value
   b. at a cold temperature value
   c. at a cold and a hot temperature value
   d. at any temperature value
2. On late EEC systems, where are fuel vapors stored [16-1]?
   a. crankcase
   b. carbon canister
   c. vapor fuel separator
   d. purge valve
3. When is the EFE system not needed [16-5]?
   a. during engine warm-up
   b. at normal engine operating temperature
   c. when the engine is operated in very cold climates
   d. none of these
4. What device acts as an overfill limiter in the EEC system [16-2]?
   a. two-way valve
   b. expansion tank
   c. both a and b
   d. neither a nor b
5. How does the ECA energize the purge solenoid [16-4]?
   a. by providing a ground
   b. by providing electrical power
   c. through a coolant-controlled vacuum valve
   d. through air pressure from the pump
6. What creates pressure in the fuel tank [16-2]?
   a. fuel pump
   b. fuel expansion
   c. cold climate
   d. high altitude
7. When is an electrical float bowl solenoid valve open [16-3]?
   a. whenever the ignition switch is on
   b. whenever the ignition switch is off
   c. whenever the throttle switch is closed
   d. whenever the throttle switch is open
8. Which type of liquid-vapor separator prevents fuel from leaking from the canister if the vehicle rolls over [16-2]?
   a. foam type
   b. standpipe type
   c. float type
   d. two-way type
9. What component stops fuel vapors from escaping from the carburetor throat and intake manifold after the engine is shut off [16-2]?
   a. canister
   b. carbon element
   c. liquid-vapor separator
   d. two-way valve
10. A typical carbon canister stores how much fuel in vapor form [16-2]?
    a. one quart
    b. one-half quart
    c. one pint
    d. one cup

Chapter 17

TESTING AND SERVICING TYPICAL EVAPORATION AND EFE SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- perform an evaporation emissions control (EEC) system inspection and flow test.
- replace a canister or its filter, a carbon element, and vent hoses.
- perform vacuum, electrical tests, or both on a three-port ported vacuum switch (PVS), canister purge solenoid, and carburetor vent solenoid.
- inspect, service, and test the early fuel evaporation (EFE) control valve.
- perform electrical tests on an EFE heater system.

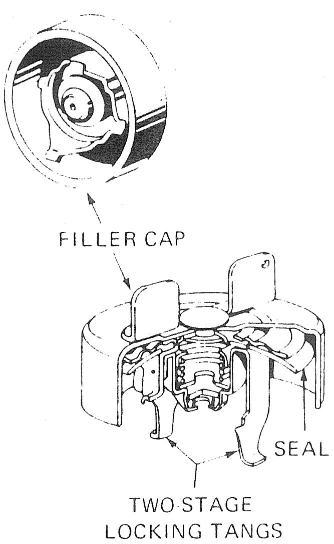


FIGURE 17-1
Filler cap inspection.

In normal service, the evaporation emissions control (EEC) system does not need a good deal of service. The reason for this is twofold. First, the system has few complex moving parts that can wear out after a period of time. Second, the system handles only clean fuel vapors; consequently, there are few problems arising due to clogging of components.

The only exception to this is the filter inside the carbon canister. Since outside air containing dust, dirt, and other contaminants passes through the filter, the element or the canister itself requires periodic replacement to prevent clogging. This, of course, would stop purge air from entering the canister and removing the fuel vapors from the granules.

Other than the replacement of the filter or canister, the only other types of routine service work include inspecting the system and replacing the carbon element or vent hoses. If the system malfunctions, the technician may also have to perform vacuum, electrical tests, or both on the PVS, purge, and carburetor vent solenoids.

As mentioned, there are a number of variations in basic EEC system design. Therefore, when servicing a particular system, *always refer to the manufacturer's instructions and specifications in the vehicle service manual.* This chapter provides some of the most common procedures used by the industry.

17-1 INSPECTING AND SERVICING TYPICAL EEC SYSTEM COMPONENTS

Unless a failure occurs to a system component, the inspection and service intervals are normally provided by the vehicle manufacturer. This may range from 12,000 miles to as much as 30,000 miles or one year to two years on the various system components.

System Inspection

To perform a visual inspection of a typical EEC system, do the following:

1. Loosen and then carefully remove the cap from the filler tube (Fig. 17-1). While doing so, check the operation of the cap's two-stage locking mechanism.

2. Inspect the cap seal for signs of deterioration. A defective seal will cause an odor by permitting the escape of gasoline vapors.

3. Check the cap's combination valve for signs of obstructions, wear, or damage. A valve that is stuck closed can cause damage to a fuel tank from high pressure or a vacuum.

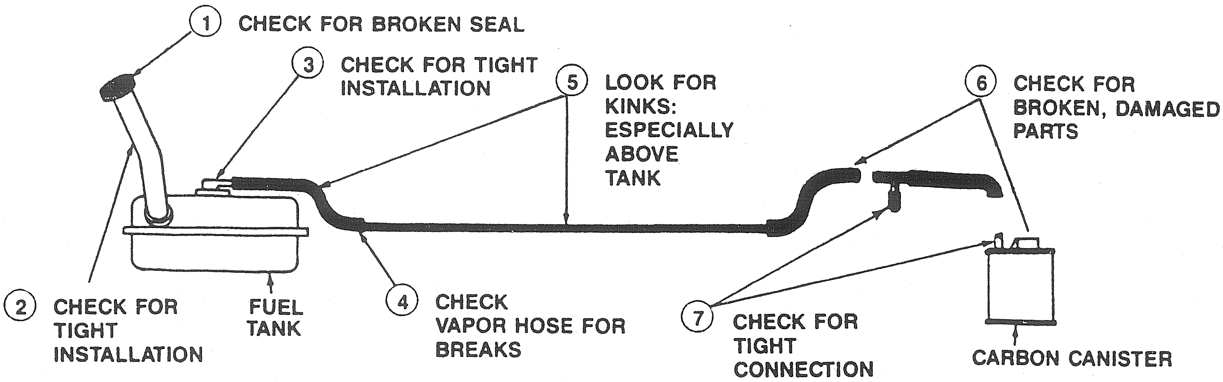


FIGURE 17-2
EEC system inspection points. (Courtesy of Ford Motor Co.)

4. If any part of the cap is defective, replace the assembly.

Caution: Serious deformation or total collapse of the fuel tank can occur if the wrong type of filler cap is installed. Make sure the cap installed is the one recommended by the manufacturer.

5. Raise the vehicle on an overhead hoist.

6. With a droplight, check the filler tube and gas tank for proper installation, security, and for signs of leakage (Fig. 17-2).

7. Inspect the liquid-vapor separator for cracks, correct installation, and fuel leakage.

8. Check the vapor hoses for proper connection to components, and signs of deterioration, breaks, and kinks.

9. Lower the vehicle to the shop floor, and open the hood.

10. Check the hose routing to the carbon canister fittings. Also, check each hose for deterioration, breaks, or kinks.

Note: A leak in any hose can cause complaints of fuel odor. Incorrect routing can result in rich engine stumble or a lack of purging and result in fuel odor.

11. Check the canister for cracks, proper installation, and presence of liquid fuel.

Note: A canister filled with fuel causes back pressure in the fuel tank. It can also cause richness or flooding symptoms during canister purge or engine start-up.

12. If accessible, inspect the canister filter for obstructions. If the filter is dirty, replace it following the procedures outlined later in this section.

13. Check the condition and routing of the vacuum hoses to the purge and carburetor vent solenoids.

14. Remove the air cleaner cover, and inspect the carbon element for obstructions. If the element is dirty, replace it using the instructions listed in this section.

EEC System Flow Test

To test a typical EEC system for blockage, do the following:

1. Install the hose from an air pump into the vent hose or line connecting the fuel tank and canister (Fig. 17-3).

2. Apply 2.5 psi to the vapor hose or line.

Caution: Do not apply more than 2.5 psi of pressure.

3. The pressure should drop immediately. If not, slowly loosen and remove the fuel cap. The pressure should now drop to zero. If not, there is a blockage in the system.

Canister or Filter Replacement

A number of canisters do not have replaceable filters. Therefore, if the filter becomes obstructed, the entire assembly must be replaced. To replace the carbon canister or its filter, do the following (Fig. 17-4):

1. Use masking tape and a pen to mark the proper location of all the canister hoses. This action prevents reinstalling a hose on the wrong fitting

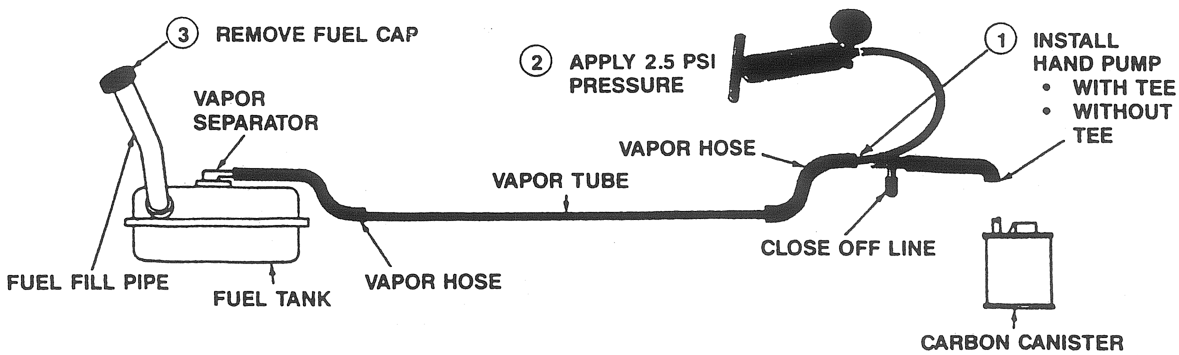


FIGURE 17-3
EEC system flow test. (Courtesy of Ford Motor Co.)

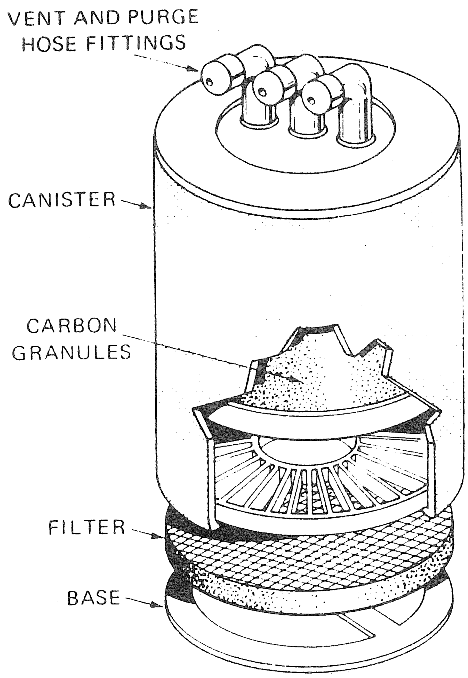


FIGURE 17-4
Replacing a canister or its filter.

when replacing the canister or filter.

2. Remove all the vapor hoses from their fittings on the canister.

3. Loosen all the hold-down clamps and then remove the canister assembly from its mount.

4. If so equipped, remove the canister base, and pull the filter element from the bottom of the unit. In some designs, the filter is held in place by a retainer bar or ring.

5. Install the new filter under the retainer bar or ring and reinstall the canister base.

6. Reinstall the canister assembly into its mount, and tighten its hold-down clamps to specifications.

7. Reinstall all vapor hoses to their proper fittings on the canister.

Carbon Element Replacement

To replace a typical carbon element, do the following (Fig. 17-5):

1. Loosen and then remove the air cleaner cover's attaching hardware. Lift the cover off the lower housing.

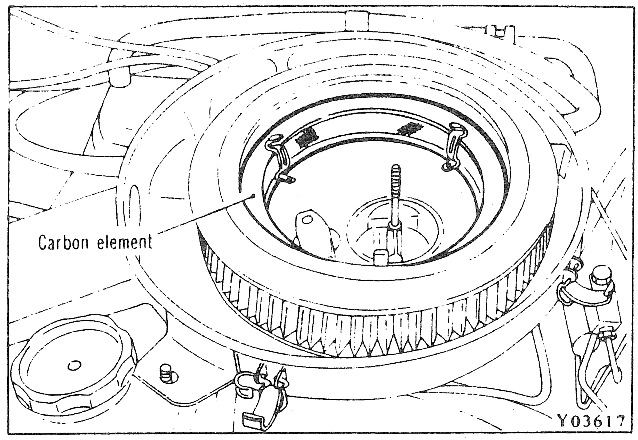


FIGURE 17-5
Replacing a carbon element. (Courtesy of Chrysler Motors Corp.)

2. Unsnap the carbon element's retaining clips, and then carefully remove the element from the housing.

3. Position the new element within the air cleaner housing. Resnap all of its retaining clips.

4. Reinstall the air cleaner cover over the lower housing and secure its attaching hardware.

Vent Hose Replacement

Any EEC vent hose requires replacement if cracked or damaged. The type of hose used for this purpose is special in that it is made especially to carry fuel vapor. Therefore, when replacing any vapor vent hose, use only the special kind designed for this application. Never use regular vacuum hose for this purpose because it will deteriorate when subjected to fuel vapors and will clog the system in time.

To replace a typical hose, do the following:

1. Loosen and slide back the hose clamps on both ends of the hose, if so equipped.

2. Slightly twist the hose around on its fittings, and then remove it using a straight, pulling action.

3. Using the original hose as a guide, cut a replacement of the correct diameter and to the proper length from a roll of hose stock.

4. Reinstall the clamps over the hose about two inches back from the ends.

5. Install the hose ends over the fittings, over-

lapping about one inch. Position and securely tighten down each hose clamp about one-quarter inch from the ends of the hose.

17-2 COMPUTERIZED EEC SYSTEM COMPONENT VACUUM AND ELECTRICAL TESTS

There are a number of vacuum and electrical tests you can perform to determine the cause of a lack of system purging or carburetor bowl venting. These include testing the three-port ported vacuum switch (PVS), the canister purge, and the fuel bowl vent solenoids.

Testing the Three-Port PVS

A failure of the three-port PVS will cause a no-canister-purge condition and in some installations an inoperative EFE vacuum control valve. To check the valve, do the following:

1. Connect two vacuum gauges to the PVS, one to the top and the other to the bottom port (Fig. 17-6).

2. Attach the hose from a vacuum pump to the PVS center port.

3. Apply five inches to ten inches of vacuum on the center port.

4. Observe the readings on the two vacuum gauges. With the engine cold, the upper gauge reading should be equal to that of the vacuum pump. The lower gauge reading should be zero.

5. Run the engine until the coolant reaches the test temperature specified by the manufacturer.

6. Again observe the readings on the two vacuum gauges. The upper gauge should now read zero, and the lower one must indicate the amount of applied vacuum.

7. Replace the PVS if it fails either the cold or hot test.

Checking a Canister Purge Solenoid

To test a canister purge solenoid for serviceability, do the following (Fig. 17-7):

1. Remove the intake manifold vacuum hose from the purge valve.

2. Connect the hose from a vacuum pump to the fitting that is now open on the purge valve.

3. Apply five inches of vacuum on the purge valve and trap. The reading on the pump gauge should remain at five inches since the purge valve is closed. It it does not, replace the valve.

4. Disconnect the wiring connector from the purge valve.

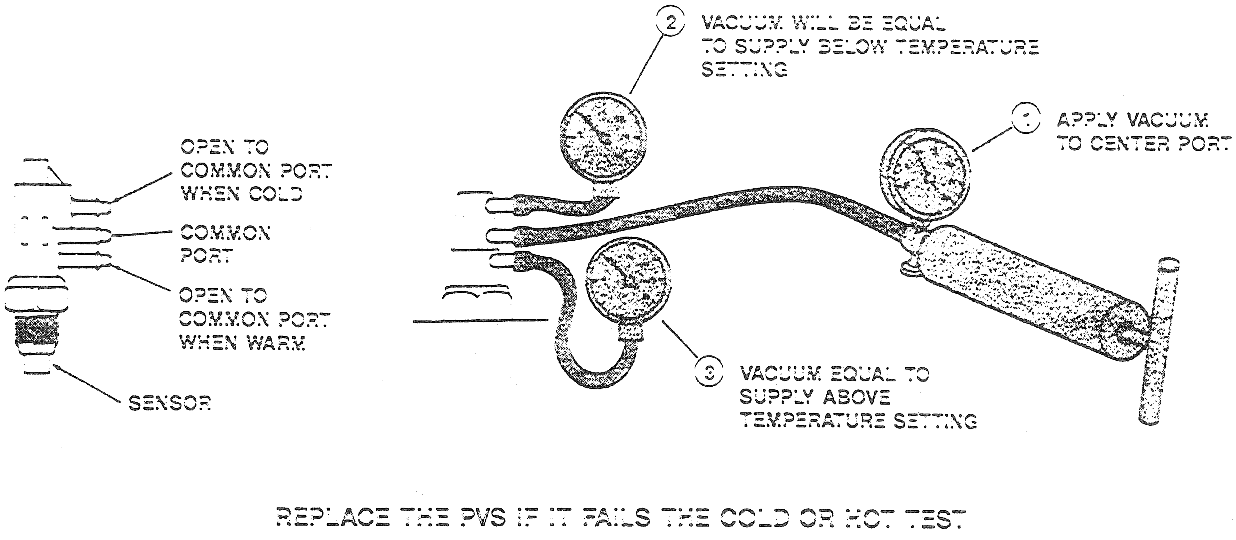


FIGURE 17-6
Testing a three-port PVS. (Courtesy of Ford Motor Co.)

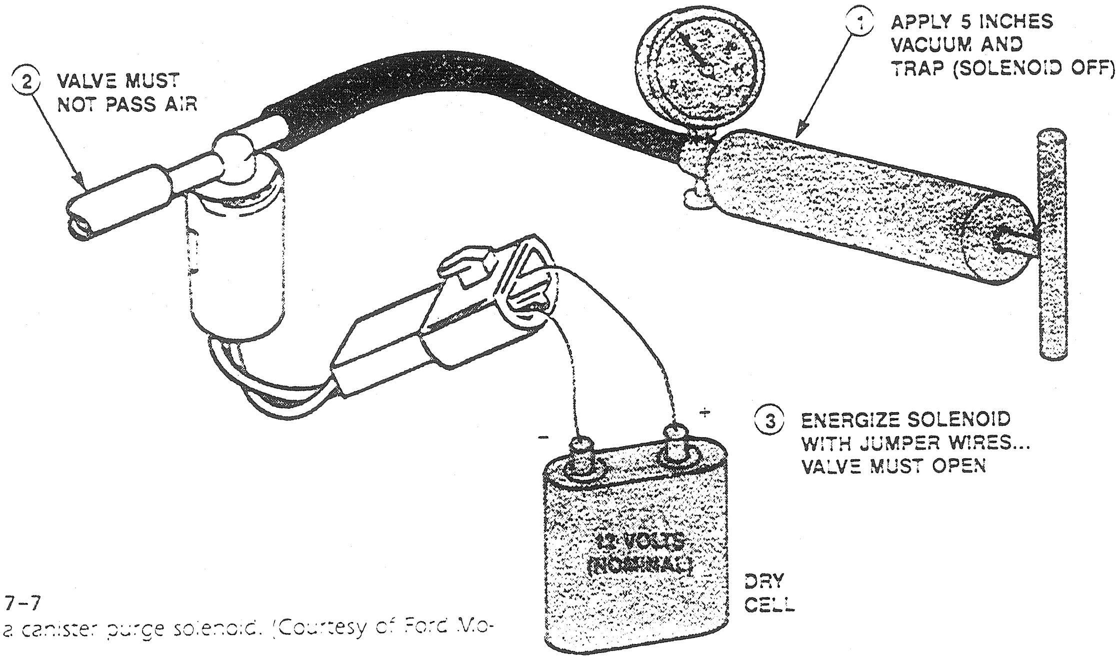


FIGURE 17-7
Checking a canister purge solenoid. (Courtesy of Ford Motor Co.)

5. With a 12-volt dry cell battery, energize the solenoid using jumper leads. The valve must open now, and the vacuum pump gauge reading must drop to zero. If not, the solenoid is defective and requires replacement.

Caution: If using the vehicle battery for this test, do not allow the jumper leads to touch each other. This will cause arcing and a possible fire or burns. For this reason, a dry cell battery is recommended for the test.

Testing a Carburetor Vent Solenoid

If the bowl vent solenoid fails to open properly, there can be engine flooding on start-up, especially after a hot engine has been shut down. A solenoid that fails to close can cause a partial vacuum over the fuel in the fuel bowl during canister purging. This can result in reduced fuel flow and lean driveability problems. To check a typical vent solenoid, do the following (Fig. 17-8):

1. Disconnect the vent hoses from the vent solenoid. Attach a clean test hose to one of the open fittings.

2. Blow air through the test hose and valve. With the solenoid de-energized, air should pass freely out the other port.

3. With a 12-volt dry cell battery and a pair of jumper leads, energize the solenoid.

Caution: If using the vehicle battery for this test, do not allow the jumper leads to touch each other. This will cause arcing and a possible fire or burns. For this reason, a dry cell battery is recommended for the test.

4. Again, attempt to blow air through the valve. Air movement should now be blocked.

5. If the vent solenoid fails any portion of this test, replace it.

17-3 INSPECTING AND SERVICING THE HEAT CONTROL VALVE EFE SYSTEM

Due to its location, the heat control valve can stick if its shaft is not lubricated regularly with graphite or heat control solvent. If the valve sticks closed, it can cause overheating, detonation, and hot engine performance problems. A valve that is stuck open can result in a poor idle or poor performance when the engine is cold. A loss of vacuum to the control motor causes the valve to remain in the open position. To prevent these problems, the heat control valve should be tested and serviced at the interval periods specified by the manufacturer.

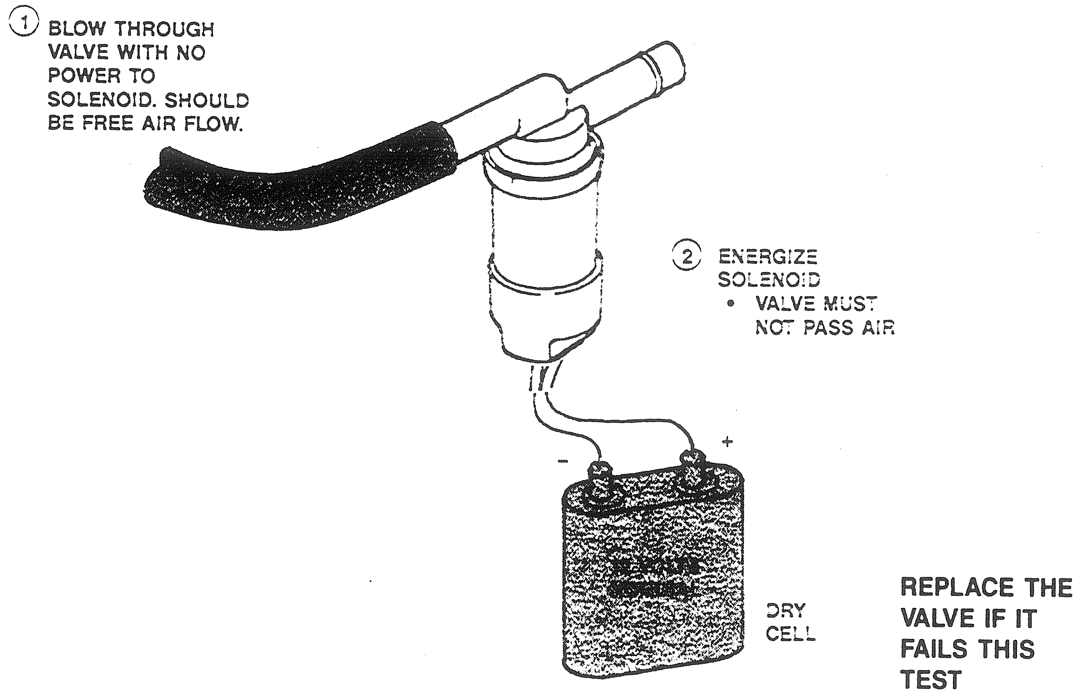


FIGURE 17-8
Testing a carburetor vent solenoid.
(Courtesy of Ford Motor Co.)

Testing and Servicing the Heat Control Valve Assembly

To test and service a typical heat control valve, do the following (Fig. 17-9):

1. Inspect the valve body for signs of cracks, gasket leakage, or other damage. Repair or replace the valve as necessary.

2. Disconnect the vacuum hose from the PVS to the motor, and install the hose from a vacuum pump to the open fitting.

3. With the pump, apply 15 inches of vacuum to the motor diaphragm and trap it for 60 seconds. The motor should not leak off more than two inches of vacuum in 60 seconds. If the motor does not hold the applied vacuum as specified, replace it.

4. While watching the position of the vacuum motor stem lever, alternately apply and release 15 inches of vacuum to the unit. The stem must move to the full position with vacuum applied and to the open position with the vacuum released.

5. Lubricate the shaft with graphite or control valve solvent as necessary.

Functional Testing of the Heat Control Valve EFE System

To perform a functional test of the heat control valve, do the following:

1. With the engine cold and shut off, note the position of the motor stem. It should be fully extended (Fig. 17-10).

2. Start the engine; the stem should not pull into the vacuum motor housing.

3. If the stem does not move, stop the engine. Attach the hose of a vacuum pump to the motor diaphragm fitting. Next, apply 15 inches of vacuum to the motor and trap. The valve stem must pull in and stay in with the vacuum trapped. Moreover, the motor can not leak off more than two inches of vacuum in 60 seconds. If it does, replace the motor assembly.

4. If the motor is okay but the valve shaft sticks, lubricate the shaft with graphite or heat control valve solvent.

5. If the valve and motor operate only with the pump attached, check the vacuum system. Check the hoses for proper routing, leaks, or restrictions.

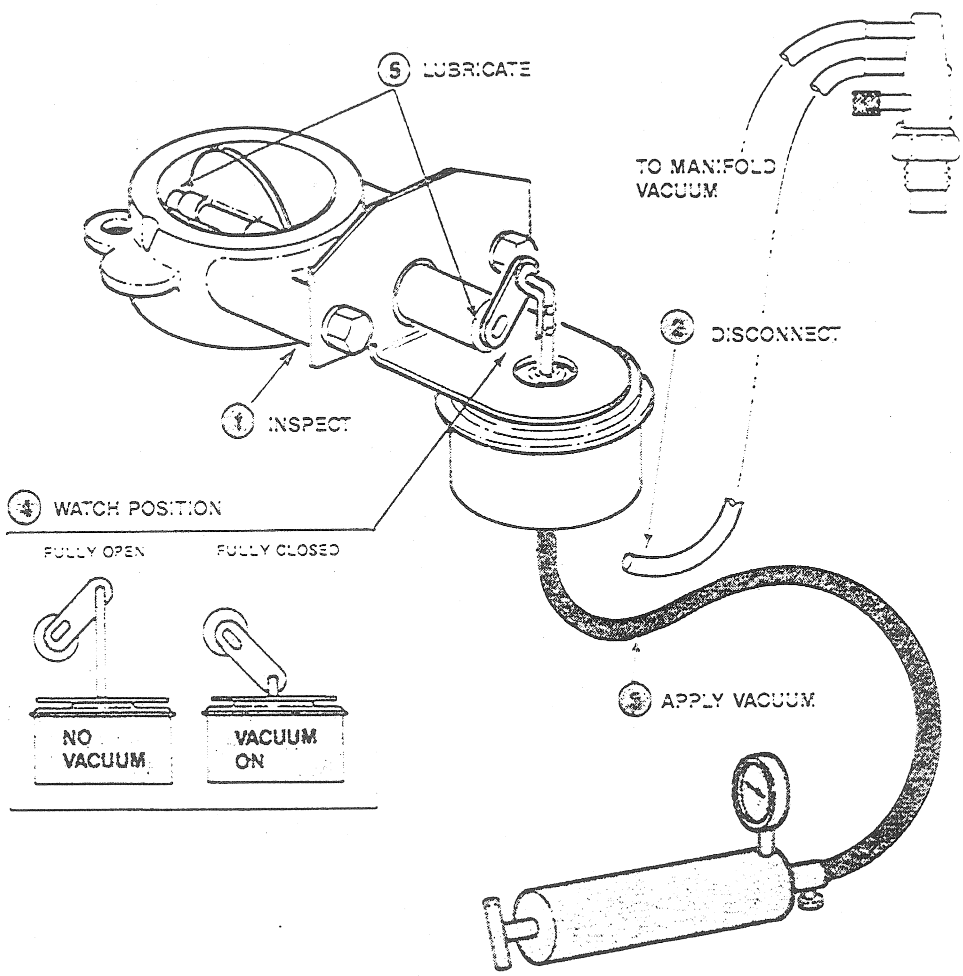


FIGURE 17-9
Testing and servicing an EFE heat control valve. (Courtesy of Ford Motor Co.)

Make repairs as necessary. If the stem still only moves by a separate vacuum source, test both the PVS and computer-controlled purge valve, as outlined in the last section.

6. If the stem pulled in during Step 2, allow the engine to warm up. When the coolant warms up, the stem should extend.

17-4 TESTING THE HEAT GRID EFE SYSTEM

A grid-type early fuel evaporation (EFE) system that is open circuited will cause no preheating of the air/fuel mixture on a cold engine. As a result, there will be engine performance problems for the first few minutes of cold operation, including poor idle, uneven acceleration, and hesitation on acceleration.

If the heater stays on for some reason, it can cause warm engine driveability complaints, including overheating, detonating, hard starting when the engine is hot, poor idling when the engine is hot, and stalling when the engine is hot.

To test the grid-type system for an open circuit, use a 12-volt test light and jumper wires, and do the following (Fig. 17-11):

1. Test for power into the relay coil. If the test light does not burn, check the circuit fuse or fusible link.

2. Disconnect and ground wire #45 to the EFE temperature switch. If the relay now clicks (energizes) and the engine is cold, the EFE temperature switch is defective and requires replacement.

3. If the relay does not click, check wire #45 and the relay coil for an open circuit.

If the relay clicks but the heater still does not

operate, follow these steps to locate the cause of the problem:

1. Check for power into the relay contact points. If the test light does not burn, replace the fusible link.

2. Test for power coming out of the relay contact points. If the test light does not burn, replace the relay assembly.

3. Check for power at the heater grid. If the test light burns, replace the heater if it will not operate.

4. If the test light did not burn, check wire #229 for an open circuit.

If the heater grid operates at all times, do the following:

1. Remove wire #45 from the EFE temperature switch. Check the heater grid. If it cools down, the EFE heater switch has failed in the closed position and requires replacement.

2. If the grid continues to heat, check wire #45 for a shorted-to-ground condition.

3. If the EFE temperature switch and wire #45 are okay and the grid continues to heat, the relay contact points are fused together. In this case, replace the relay assembly.

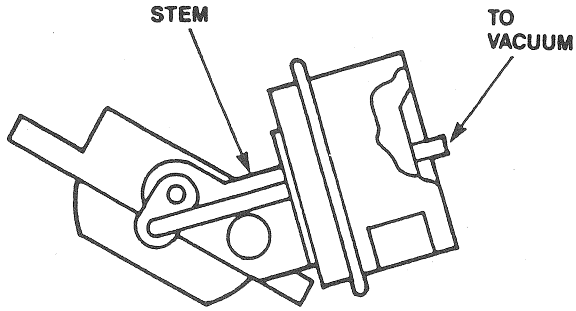
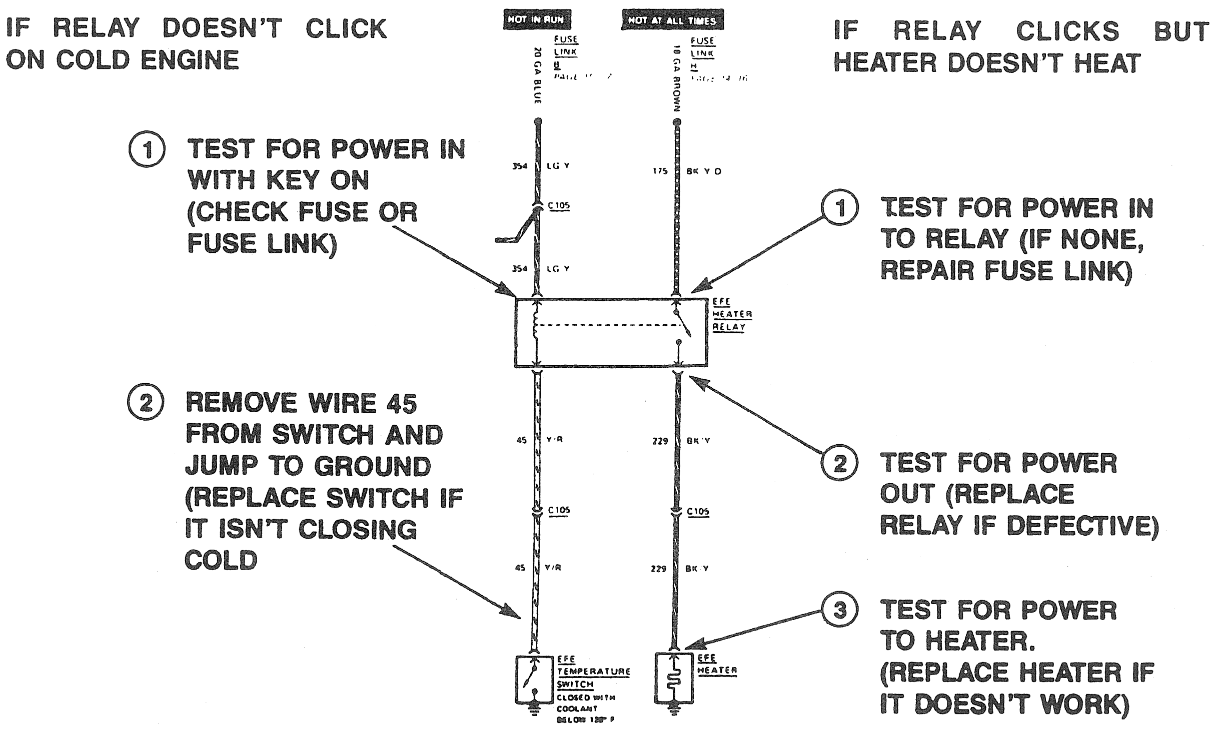


FIGURE 17-10
Functional checking of an EEF control valve system. (Courtesy of Ford Motor Co.)

FIGURE 17-11
Testing a heater-type EFE system with a 12-volt light and jumper leads. (Courtesy of Ford Motor Co.)



CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. Explain what can occur if an EFE heater grid does not turn off [17-4].
2. Why is it important to use the proper stock when replacing a vent hose [17-1]?
3. Describe the problems associated with a malfunctioning heat control valve [17-3]?
4. What problems will a defective three-port PVS cause [17-2]?

REVIEW

1. An engine that detonates can result from a defective what [17-3 and 17-4]?
   Technician A says the EFE system.
   Technician B states the EEC system.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
2. If the combination valve in an EEC filler cap fails to open, what can happen [17-1]?
   Technician A replies the fuel tank can collapse.
   Technician B says the fuel tank can deform or burst.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
3. If the EFE heater remains on, what can be the cause [17-4]?
   a. defective relay
   b. defective EFE temperature switch
   c. grounded temperature switch wire
   d. all of the above
4. What will occur if the canister filter is clogged [17-1]?
   Technician A states the collected vapors will not be properly purged.
   Technician B replies the fuel tank will pressurize.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
5. A failed carburetor vent solenoid will cause what problem [17-2]?
   Technician A says flooding on a cold engine start-up.
   Technician B states flooding on a hot engine start-up.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
6. If a computer-controlled heat control valve is serviceable but did not pass the functional test, check what [17-3]?
   Technician A replies the PVS.
   Technician B states the purge valve.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b

Chapter 18

FORD COMPUTERIZED ENGINE CONTROL SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- explain the function, design, and basic operation of the Ford EEC-I system.
- describe the design, function, and operation of the Ford EEC-II system.
- explain the purpose, design, and basic operation of the Ford EEC-III system.
- describe the design, function, and basic operation of the Ford EEC-IV system.
- explain the function, design, and operation of the Ford microprocessor control unit (MCU) system.

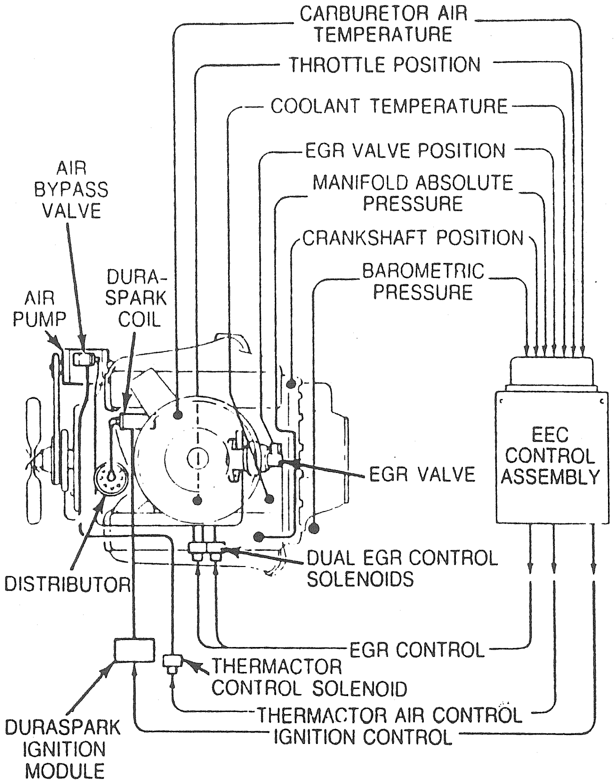


FIGURE 18-1
EEC-I system. (Courtesy of Ford Motor Co.)

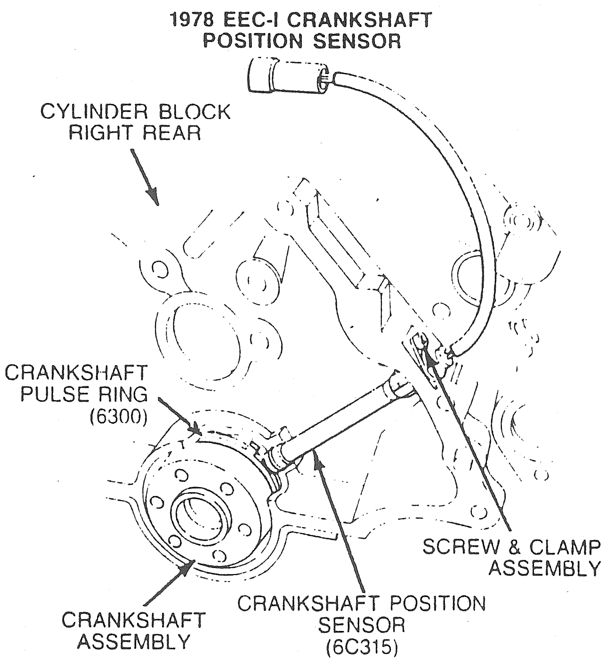


FIGURE 18-2
CP sensor design and location. (Courtesy of Ford Motor Co.)

Up to this point, this text has introduced the basic theory of electricity, electronics, and microcomputer operation. Furthermore, it has covered in detail the function, design, operation, and testing of the many subsystems found within engine control systems. It is now time to assemble all this data together and examine the complete system.

To accomplish this task, the next two chapters provide information on the function, design, and operation of the domestic Ford systems, and on how to test them for malfunctions. In later chapters, General Motors and Chrysler systems will also be covered.

Before beginning, there is one important thing to remember. Previous chapters have already provided a lot of detailed information about most of the components you are about to study. Therefore, if at any time there is some point you do not understand, use the index or table of contents and go back and restudy the subject material found in earlier sections of the text.

18-1 FORD EEC-I SYSTEM

In 1978, Ford Motor Company introduced its first *electronic engine control system, the EEC-I* (Fig. 18-1). This system only controls ignition timing, EGR flow, and Thermactor air. The system cannot operate in closed loop and, therefore, cannot alter the air/fuel ratio since it does not have an exhaust gas sensor.

The system has seven input sensors, including crankshaft position, throttle angle position, EGR valve position, manifold absolute pressure, barometric pressure, engine coolant temperature, and inlet air temperature.

Input Sensors

Crankshaft Position Sensor. The *crankshaft position (CP) sensor* is in the system to monitor the relative location of the crankshaft at any given moment. A signal developed by the sensor then informs the microcomputer when each piston reaches top dead center (TDC). The microcomputer uses this information to control ignition timing at given engine speeds.

The CP sensor operates by magnetic induction and consists of a pulse ring, magnet, and coil (Fig. 18-2). The *pulse ring* is a thin (approximately ¼-inch) steel plate with four equally spaced lobes 90 degrees apart. The ring is pressed on the rear end of

the crankshaft in a position ten degrees in advance of the TDC point. This determines the engine's initial or reference timing at ten degrees before top dead center (BTDC).

Since the crankshaft rotates twice to each distributor shaft rotation, only four lobes are necessary for an engine with eight cylinders. As the crankshaft turns, each lobe on the ring passes by the tip of the CP sensor.

The CP sensor mounts on the rear of the engine block, and a small air gap exists between the sensor tip and the pulse ring. Moreover, the sensor is held in position by a retaining clip and screw and requires no adjustment once it is installed.

The sensor tip contains a permanent magnet and a coil. As the lobes of the pulse ring pass under the permanent magnet in the probe tip, there is a reduction in the air gap. This causes a sudden increase in the strength of the magnetic field emitted from the pole of the magnet. This sudden change in the magnetic field strength induces an output voltage into the coil wound around the magnet (Fig. 18-3). This voltage is relayed to the input conditioner of the microcomputer. As mentioned, the microcomputer uses this signal to derive engine rpm information needed for spark advance and to provide the reference timing signal of ten degrees.

If this sensor, its interconnecting harness, or connector fails, the engine will not start. The reason for this is that the sensor signals the microcomputer when to trigger the ignition module on and off.

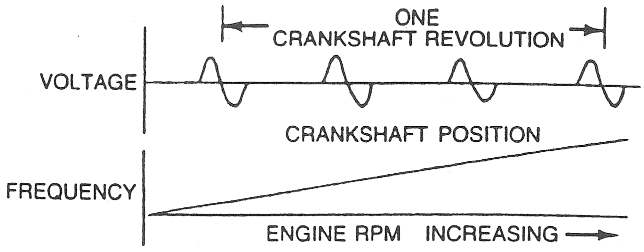


FIGURE 18-3
CP voltage signals. (Courtesy of Ford Motor Co.)

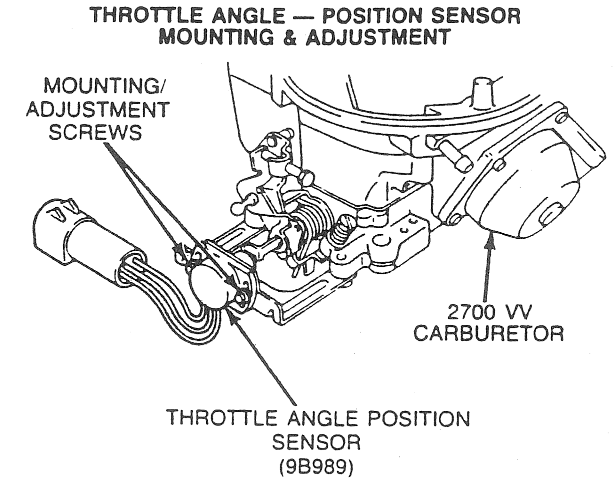


FIGURE 18-4
TAP sensor. (Courtesy of Ford Motor Co.)

Throttle Angle Position Sensor. The *throttle angle position (TAP) sensor* is a mechanically operated potentiometer that develops a voltage signal in relation to the position of the carburetor throttle valve. To perform this function, the sensor is coupled to the carburetor shaft and mounts on a special bracket (Fig. 18-4).

The microcomputer applies a reference voltage of about nine volts to the sensor. The sensor then produces an output signal that reflects three modes of engine operation: (1) closed throttle either at idle or deceleration, (2) part throttle (normal cruise operation), and (3) wide-open throttle indicating maximum acceleration.

The TAP sensor signals are the electrical equivalent of the carburetor spark and EGR vacuum signals in noncomputerized systems. These electrical signals supply the microcomputer with rate of acceleration information. These data are an indication of driver demand and are used to determine the proper amount of spark advance, EGR flow, and Thermactor air injection.

The TAP sensor mounting holes are slotted to allow rotational adjustment. If the sensor is replaced, it has to be correctly positioned or erroneous throttle angle information is sent to the microcomputer.

EGR Valve Position Sensor. The *EGR valve position (EVP) sensor* is a vacuum- and diaphragm-operated potentiometer (Fig. 18-5). This sensor also receives a reference voltage signal from the microcomputer and then from it develops an output signal in proportion to the EGR valve pintle position. The microcomputer uses this signal to determine the actual EGR flow rate at any point in time.

Manifold Absolute Pressure (MAP) Sensor. The *manifold absolute pressure (MAP) sensor* (Fig. 18-6) consists of an aneroid that moves the wiper of a potentiometer. The *aneroid* is an accordionlike capsule that contains a gas at atmospheric pressure. With this design, the aneroid compresses if the outside pressure increases over atmospheric and expands if the pressure is lower.

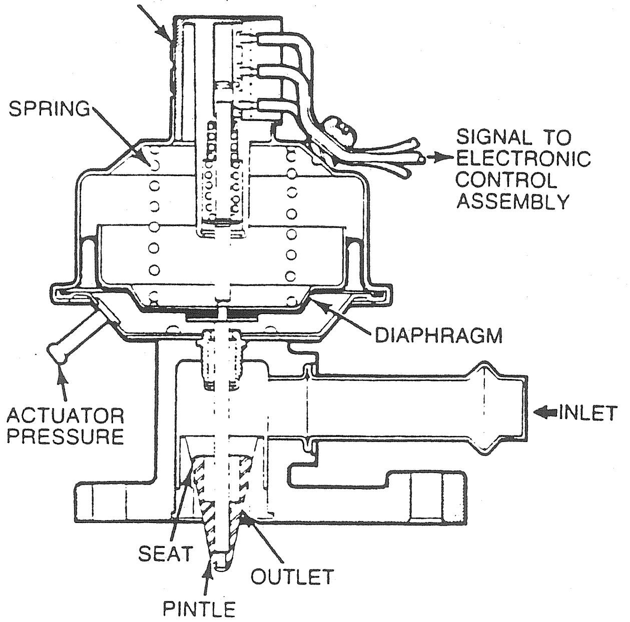


FIGURE 18-5
EVP sensor. (Courtesy of Ford Motor Co.)

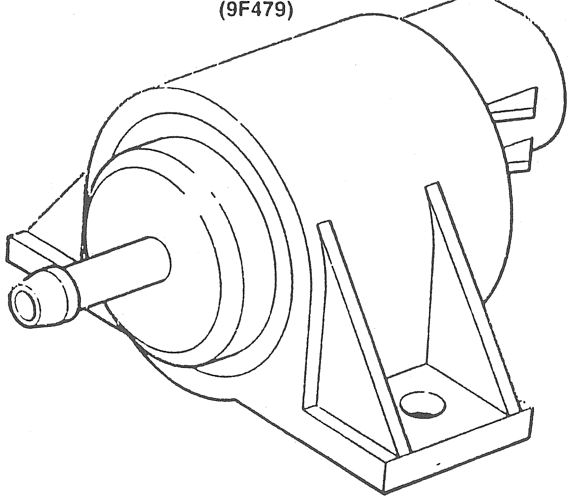


FIGURE 18-6
MAP sensor. (Courtesy of Ford Motor Co.)

The aneroid and potentiometer are inside a housing connected to the intake manifold vacuum. With changes in manifold vacuum, the aneroid contracts or expands. This action moves the wiper of the potentiometer to change the reference input voltage to an output signal to the microcomputer that is in proportion to manifold absolute pressure.

Manifold absolute pressure is defined as atmospheric pressure minus manifold vacuum. Absolute

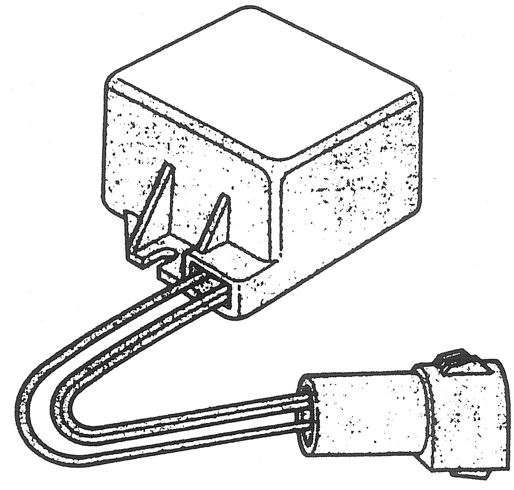


FIGURE 18-7
BP sensor. (Courtesy of Ford Motor Co.)

pressure changes due to variations in engine load, speed, and atmospheric pressure. The microcomputer uses the signals representing manifold absolute pressure to determine part-throttle spark advance and EGR gas flow.

Barometric Pressure Sensor. The *barometric pressure (BP) sensor* operates in much the same manner as the MAP, except that it is ported to atmospheric pressure instead of the intake manifold (Fig. 18-7). The microcomputer also supplies a reference voltage to the BP sensor, and it produces an output voltage signal in proportion to changes in atmospheric pressure caused by variations in weather conditions or vehicle altitude.

The microcomputer uses this signal to alter the amount of EGR flow. A vehicle driven in higher altitudes requires less EGR flow, for example, than one operated at sea level. Through the use of the BP signal, the microcomputer can perform altitude compensation of EGR flow.

Engine Coolant Temperature Sensor. The *engine coolant temperature (ECT) sensor* is a thermistor that is assembled into a brass housing (Fig. 18-8). The unit has a two-wire pigtail harness with a connector that extends from the sensor housing. In addition, the sensor mounts in a water passage located at the rear of the intake manifold.

The microcomputer supplies a reference voltage to the ECT. Since the sensor is a thermistor device, its resistance changes with temperature. As a result, the output signal from the ECT (i.e., change

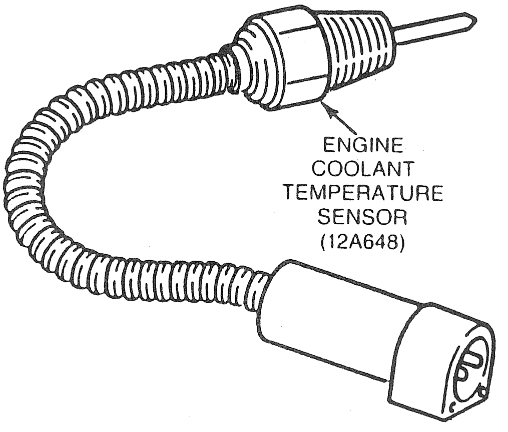


FIGURE 18-8
ECT sensor. (Courtesy of Ford Motor Co.)

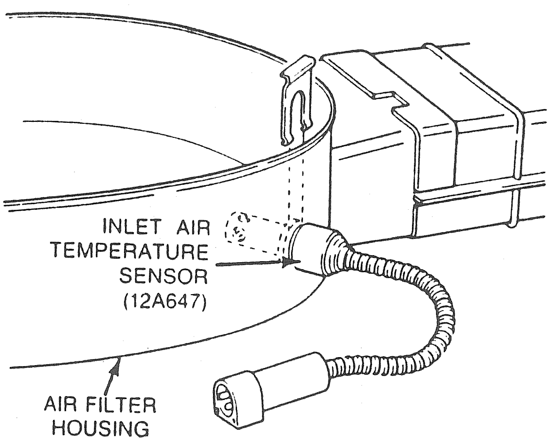


FIGURE 18-9
Inlet air temperature sensor. (Courtesy of Ford Motor Co.)

in reference voltage strength) is in proportion to varying coolant temperatures.

The ECT sensor is also used by the microcomputer to control EGR gas flow. For instance, if the engine coolant temperature is less that 70°F (21°C) or greater than 230°F (110°C), the microcomputer uses the ECT signal to cut off EGR gas flow.

Moreover, periods of prolonged idle can result in engine overheating. Under these conditions, the ECT signal to the microcomputer advances the ignition timing. This action provides increased engine speed, which improves the efficiency of the engine's cooling system.

Inlet Air Temperature Sensor. The *inlet air temperature sensor* is also a thermistor device and is very similar in design and operation to the ECT sensor. The air inlet sensor mounts in the air cleaner housing near the duct and valve assembly (Fig. 18-9). The noticeable design difference between the two sensors is that the inlet temperature sensor has a protective shield near its tip that has a series of holes. These allow the sensor to respond quickly to sudden changes in inlet air temperature.

The sensor's internal resistance alters the reference input voltage in proportion to the air temperature. The microcomputer uses the signal for two purposes. First, above 90°F (32°C), the microcomputer modifies the amount of spark advance as necessary to avoid detonation. Second, the signal is used by the microcomputer to determine the proper operating period of Thermactor air injection.

EEC-I System Outputs

EGR Control Solenoids. The EEC-I system utilizes three output control devices: the EGR solenoids, the Thermactor air control solenoid, and the ignition module. The microcomputer controls actual EGR valve movement through the use of two solenoid valves, a pressure and a vent, that mount on a bracket above the left rocker arm cover (Fig. 18-10). The vent solenoid is a normally open unit, meaning its outlet port is open to the atmosphere when deenergized. However, whenever energized by the microcomputer, the solenoid valve closes. The pressure valve, on the other hand, is closed whenever the unit is de-energized and open when energized.

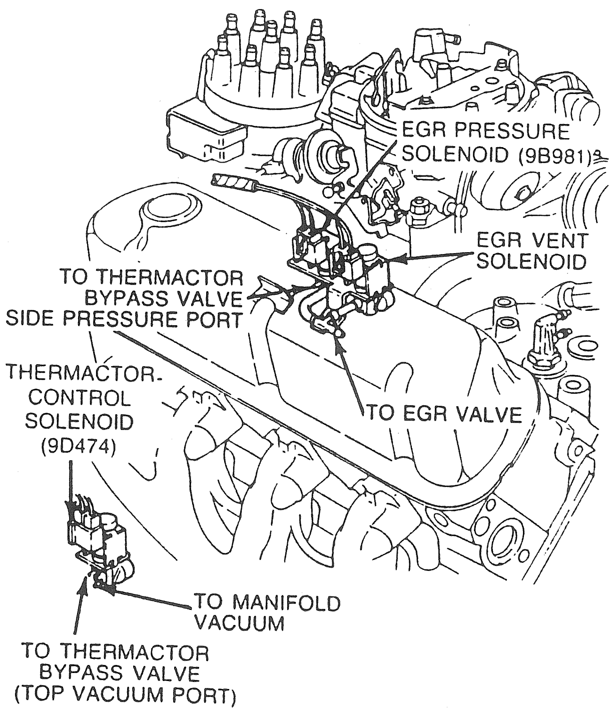


FIGURE 18-10
EGR and Thermactor control solenoids. (Courtesy of Ford Motor Co.)

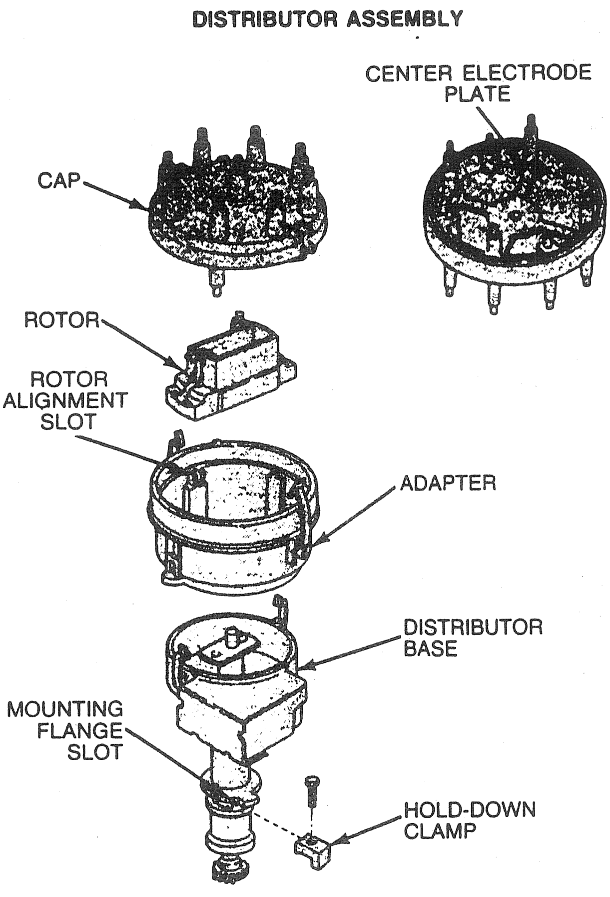


FIGURE 18–11
EEC-I distributor and cap. (Courtesy of Ford Motor Co.)

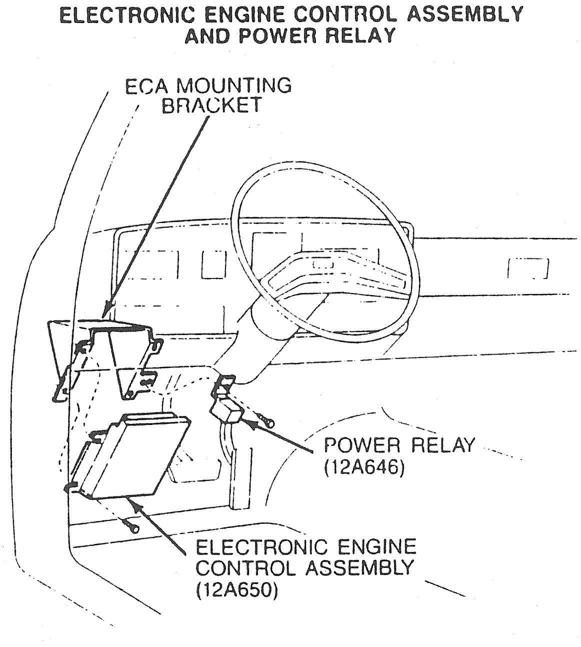


FIGURE 18–12
ECA location. (Courtesy of Ford Motor Co.)

These solenoids, when activated by a microcomputer output signal, control the application of air pressure from the Thermactor system to the EGR valve diaphragm. The solenoids are able to apply and trap whatever air pressure is necessary to hold the diaphragm and attached pintle valve in any given open position.

About ten times every second, the microcomputer monitors the signal from the EGR valve position sensor and compares this with the desired position stored in memory. Then, the microcomputer makes necessary position adjustments to maximize accuracy. The continuous monitoring of the pintle position by the sensor allows the microcomputer to provide precise control of EGR flow for improved economy and driveability.

Thermactor Air Control Solenoid. The *Thermactor air control solenoid* (Fig. 18-10) mounts on the backside of the left shock absorber tower. This solenoid is a normally closed unit that is identical in operation to the EGR pressure solenoid valve. However, the lower port of this solenoid connects to the manifold vacuum and the upper port connects to the Thermactor bypass valve.

When the microcomputer supplies a ground for the solenoid, it energizes. The solenoid valve now opens and a vacuum signal from the intake manifold can pass to the Thermactor bypass valve. As a result, Thermactor air is injected into the cylinder head exhaust ports. When the microcomputer breaks the solenoid ground, the unit de-energizes and the valve closes. This cuts off the intake manifold signal to the bypass valve. Consequently, the bypass valve dumps Thermactor air to the atmosphere. To determine when to energize or de-energize the Thermactor solenoid, the microcomputer uses both inlet air temperature and throttle angle position sensor signals.

Ignition Module The ignition system used with the EEC-I consists of a redesigned distributor, a standard Duraspark II module, and a coil. The EEC-I distributor (Fig. 18-11) has no provision for centrifugal or vacuum-advance mechanisms. This means the distributor base contains no calibration springs or weights. Moreover, since the EEC-I system has a CP sensor, the distributor does not have a magnetic pickup coil. Consequently, the main function of the distributor is to route the coil's secondary voltage to the appropriate spark plug.

Deletion of the advance mechanisms is possible because the microcomputer takes over the function of timing control. The microcomputer accomplishes

this by providing an output signal to the ignition module (see Fig. 18-1). This signal makes or breaks the primary coil circuit through the module's switching transistor. When the circuit is broken, there is high voltage generated in the secondary coil that is then routed by the distributor to the appropriate spark plug.

Electronic Control Assembly

The microcomputer used in the EEC-I system is known as the *electronic control assembly (ECA)*. The ECA is located inside the passenger compartment. There it mounts behind the instrument panel near the brake pedal support on the driver's side (Fig. 18-12).

The ECA is the brain of the EEC-I system. It relies on inputs from the seven sensors to perform its calculations and then provides output signals to the ignition, EGR, and Thermactor systems. The ECA is a solid-state, preprogrammed microcomputer consisting of two parts, the processor and the calibration assembly (Fig. 18-13).

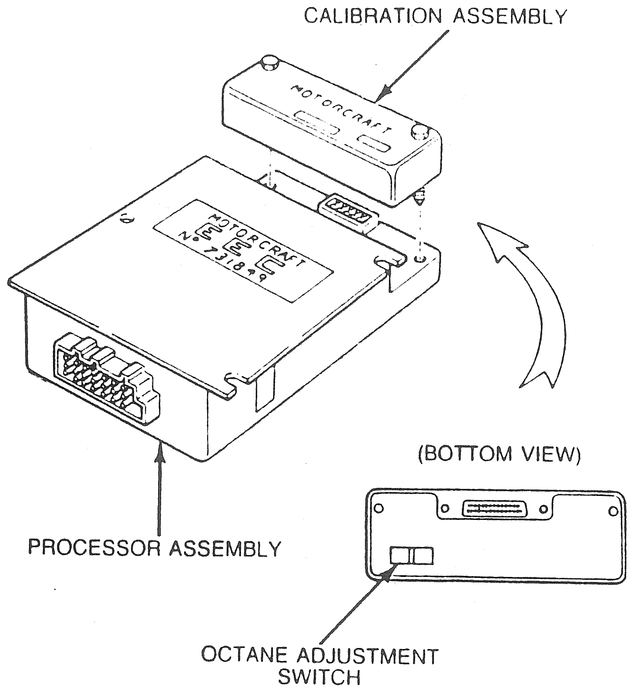


FIGURE 18-13
ECA component parts. (Courtesy of Ford Motor Co.)

Processor Assembly

The *processor assembly* consists of an aluminum case that houses sophisticated electronic circuits. The assembly also contains a separate power supply that provides a continuous reference voltage (VREF) of about nine volts to the sensors.

The processor assembly has the ability to perform four important tasks within a fraction of a second. These include (1) choosing any of the seven sensor input signals for analysis, (2) converting the chosen signal to a format that allows the microcomputer to use the information in making calculations, (3) performing spark advance, EGR flow, and Thermactor air injection calculations, and (4) directing electrical output signals to the ignition module and control solenoids in order to adjust timing, EGR flow, and air injection operation.

Calibration Assembly

The *calibration assembly* is enclosed in a plastic case that houses additional special electronic circuitry. The assembly attaches to the top inner surface of the processor by means of two screws.

On the bottom side of the calibration assembly is a *fuel octane adjustment switch*. This slide switch enables a technician to retard the initial timing either three degrees or six degress from the factory setting if a spark knock exists in a properly operating EEC-I system.

The electronic circuits within the calibration assembly are capable of providing the processor assembly with unique calibration data that relate to that particular vehicle application; storing the data calculated by the processor assembly; and recalling from its memory, as required, any stored data.

EEC-I Operation

As mentioned, the EEC-I system uses seven sensors. The three position sensors are the crankshaft, throttle, and EGR valve. The two pressure sensors include the manifold absolute and the barometric. The final two temperature sensors are the engine coolant and the air inlet (Fig. 18-14).

These seven sensors constantly monitor their assigned functions and direct signals back to the ECA for analysis. The ECA instantaneously computes the correct amount of timing advance, EGR flow rate, and air injection requirements for a given instant of vehicle operation. Finally, the ECA sends output signal commands to the EGR solenoids, Thermactor air control solenoid, and the ignition module.

If, for some reason, there is an ECA failure, the

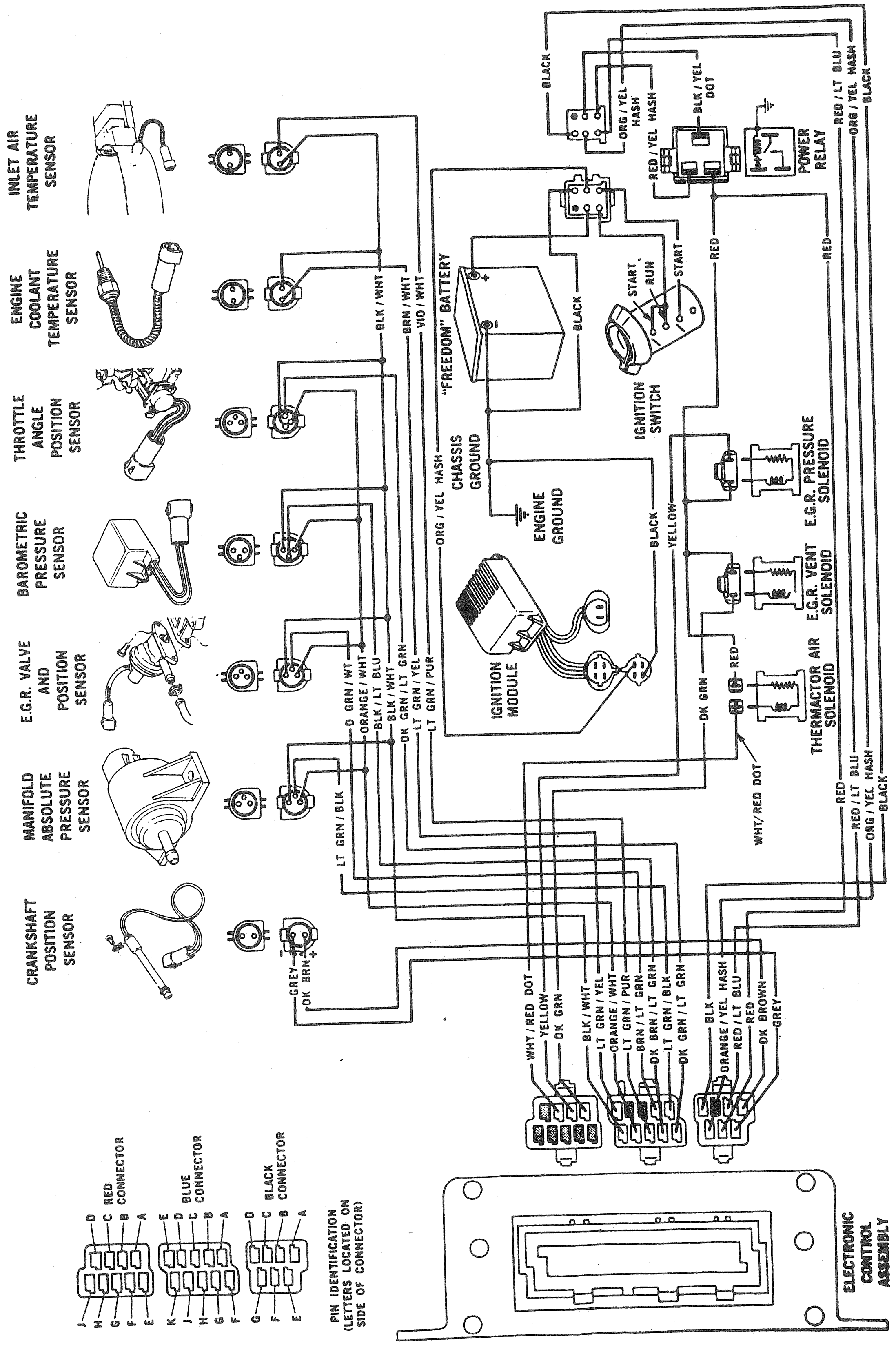


FIGURE 18–14
EEC-I operation. (Courtesy of Ford Motor Co.)

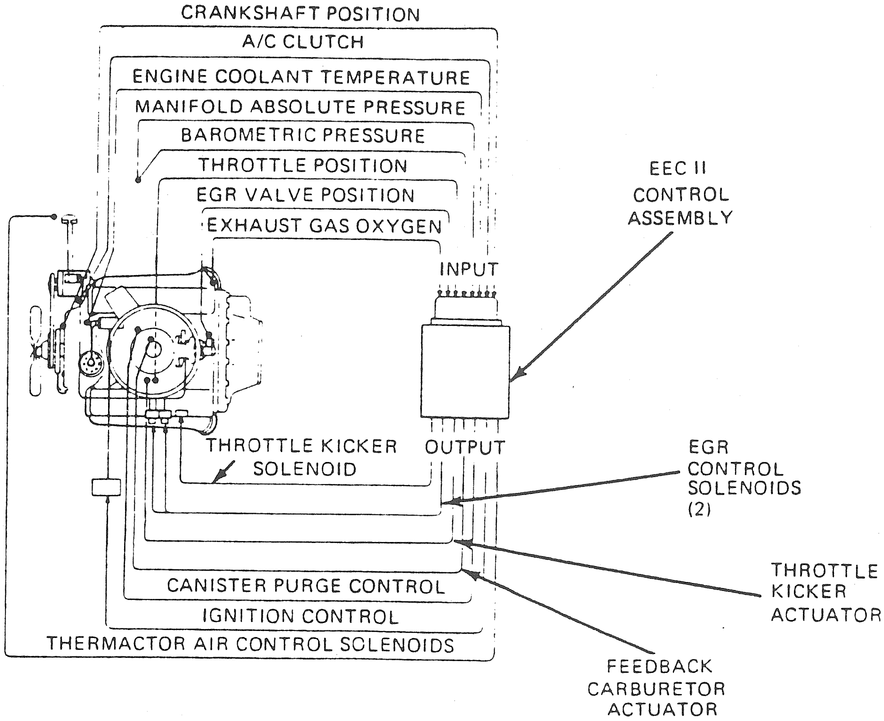


FIGURE 18-15
EEC-II system. (Courtesy of Ford Motor Co.)

system goes into a default mode of operation. In this mode, the three output commands are cut off. The engine continues to operate but has no additional spark advance other than initial, regardless of sensor inputs. The vehicle can still be operated until repairs are performed, but the engine performs poorly.

18-2 FORD EEC-II SYSTEM

Ford Motor Company introduced the EEC-II system in 1979 (Fig. 18-15). This system is similar to EEC-I. However, it not only controls ignition timing, EGR flow, and air injection operation, it also regulates the air/fuel ratio, idle speed, and canister purging. To accomplish this, the EEC-II system uses seven input sensors and controls seven output actuators.

System Input Sensors

Crankshaft Position. The crankshaft position sensor for the EEC-II system operates in the same way as the one used on EEC-I. However, its location and design are different (Fig. 18-16). The CP sensor for the EEC-II system mounts in the front of the engine block instead of the rear. Moreover, the pulse ring,

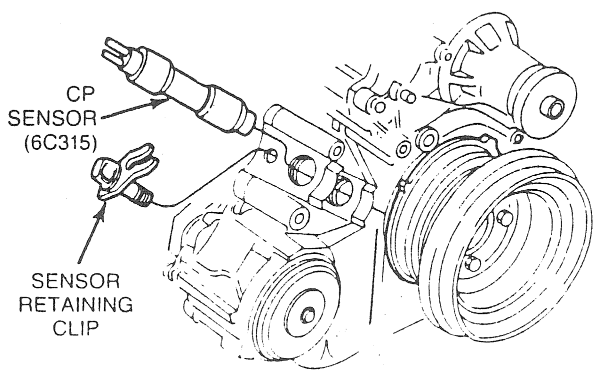


FIGURE 18-16
EEC-II CP sensor location. (Courtesy of Ford Motor Co.)

instead of being on the rear of the crankshaft, is moved to the front.

The sensor has an extra connector (Fig. 18-17). It is used for shielding to prevent any electrical interference from causing false or incorrect signals to the ECA.

Throttle Position Sensor. The throttle position sensor is identical to the one used on the EEC-I system. The only difference is that its name is changed from throttle angle position (TAP) to *throttle position (TP) sensor.* The TP sensor is still mounted on the side of the carburetor and receives the nine-volt

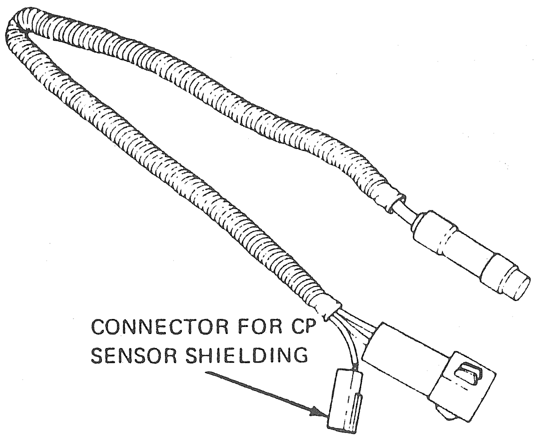


FIGURE 18-17
EEC-II CP sensor design. (Courtesy of Ford Motor Co.)

reference signal from the microcomputer (Fig. 18-18).

The output signal from the sensor is still an indication of driver demand. The signal allows the microcomputer to determine the correct amount of spark advance, air injection operation, and air/fuel ratio to match a given phase of engine operation.

EGR Valve Position Sensor. The EGR valve position (EVP) sensor still mounts on the top of the EGR valve as it did in the EEC-I system (Fig. 18-19). Its purpose remains the same; that is, the EVP sensor monitors the position of the EGR valve pintle. The sensor then directs a data signal to the microcomputer. This permits the microcomputer to determine the actual EGR flow at any given time.

Barometric and Manifold Absolute Pressure Sensor. In the EEC-I system, the barometric and manifold absolute pressure sensors are two separate units. However, the EEC-II system utilizes a combined assembly known as the *barometric and manifold absolute pressure (B/MAP) sensor* (Fig. 18-20). The B/MAP sensor still monitors the values of intake manifold absolute and atmospheric pressures, as did the two units used in the EEC-I system.

The B/MAP sensor converts the microcomputer reference input voltage signal to one proportional to barometric and absolute pressures. The microcomputer uses this input signal to calculate spark advance, EGR flow, and air/fuel ratio requirements.

Engine Coolant Temperature Sensor. The *engine coolant temperature (ECT) sensor* used with the EEC-II system is also a thermistor assembled into a brass housing with an integral connector extending from the body (Fig. 18-21). The main difference between the EEC-II sensor and the one used on EEC-I is that the connector used on the latter attached to the pigtail, which connected to the sensor housing. Both sensors mount into an intake manifold coolant passage.

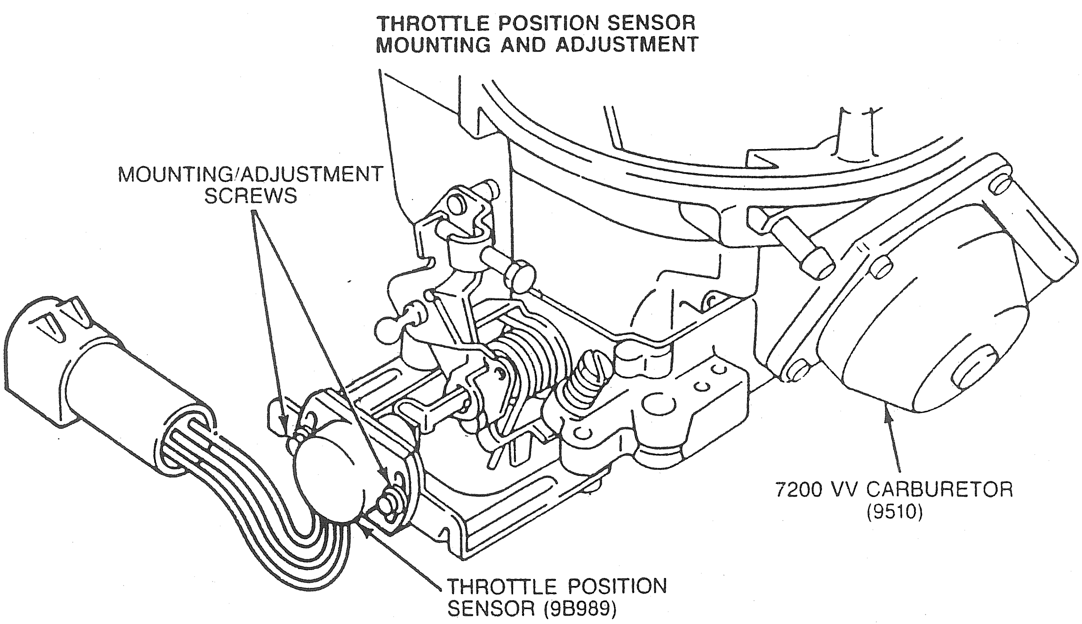
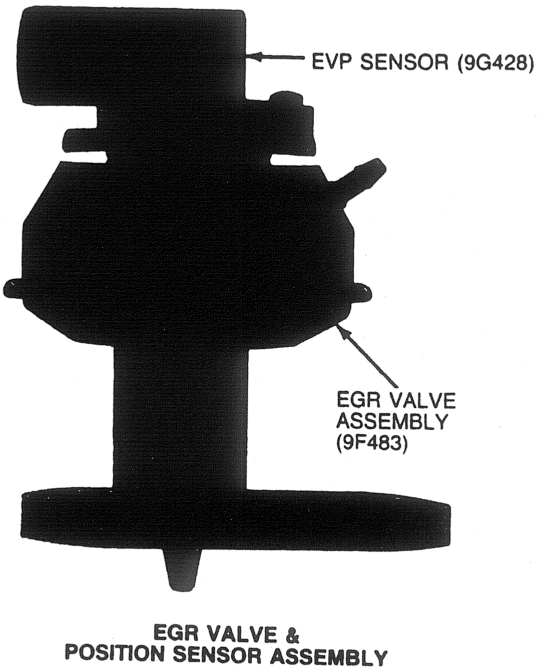


FIGURE 18-18
EEC-II TP sensor. (Courtesy of Ford Motor Co.)



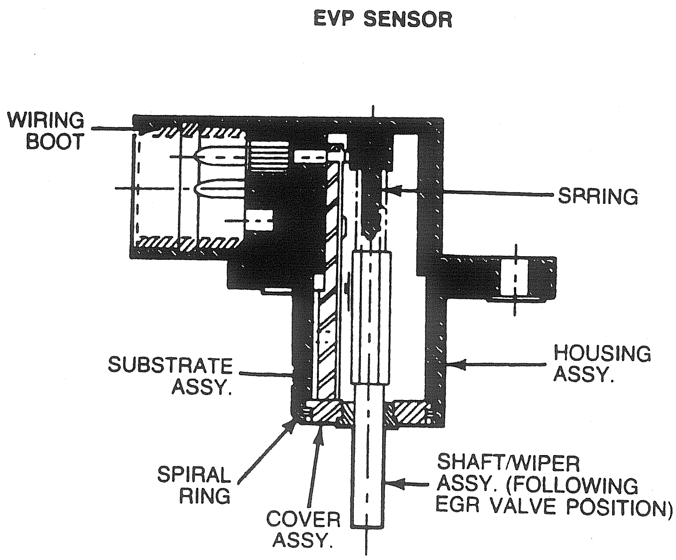


FIGURE 18-19
EEC-II EVP sensor. (Courtesy of Ford Motor Co.)

However, the function of the ECT sensor remains the same. That is, it converts the input reference voltage signal to one proportional to the temperature of the engine coolant. The microcomputer uses the ECT signal in the EEC-II system to control or modify the air/fuel ratio, EGR flow, air injection, canister purging, and engine idle speed.

Exhaust Gas Oxygen Sensor. The *exhaust gas oxygen (EGO) sensor* is a high voltage-generating device that threads into the exhaust manifold directly in the path of the exhaust gas stream (Fig. 18-22). The EGO sensor generates an output voltage signal that is in proportion to the air/fuel ratio, as indicated by the oxygen concentration within the exhaust gases.

When the EGO sensor detects a rich exhaust gas mixture (i.e., one low in oxygen content), it generates an output voltage ranging from 0.60 volt to 1.00 volt. On the other hand, a low output voltage of 0.40 volt or less is generated when the unit senses a lean exhaust gas mixture (i.e., one high in oxygen concentration). However, the EGO sensor can only send the microcomputer an accurate signal after its tip temperature reaches about 660°F (249°C).

The microcomputer uses this changing EGO voltage signal for one purpose. That is, the signal allows the microcomputer to alter the air/fuel ratio during the closed loop phase of system operation.

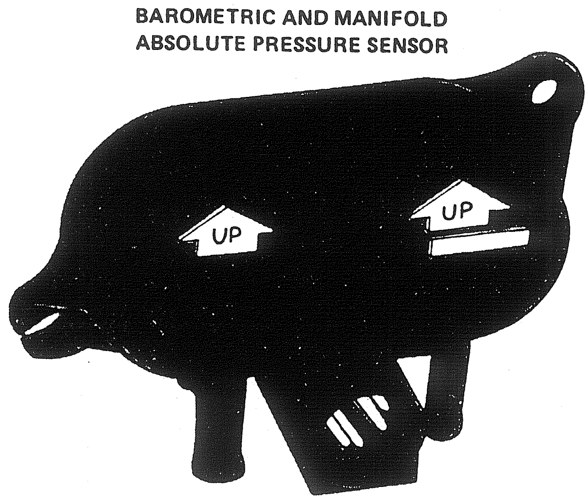


FIGURE 18-20
B/MAP sensor. (Courtesy of Ford Motor Co.)

System Output Actuators

EGR Control Solenoids. In the EEC-II system, the control of EGR diaphragm and valve movement is regulated by two solenoids (Fig. 18-23). These units mount on a bracket attached to the left rocker arm cover. The normally open vent solenoid is located closest to the rear of the engine. Forward of it is the normally closed EGR control solenoid. Both

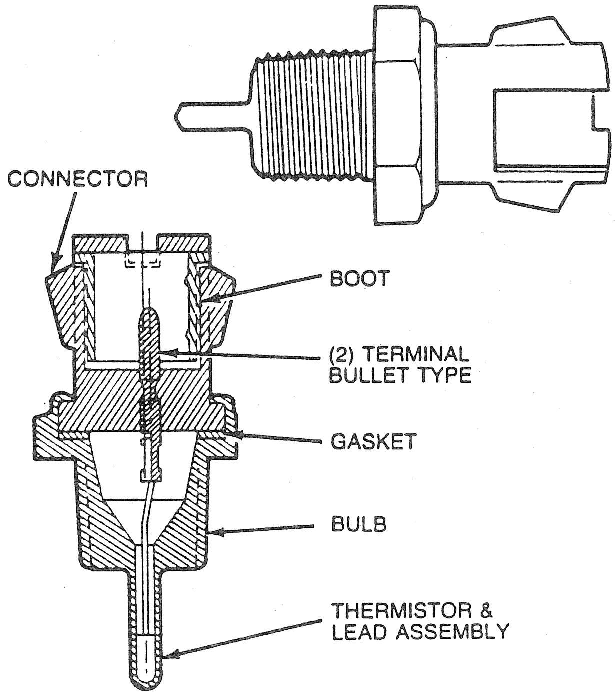


FIGURE 18-21
EEC-II ECT sensor. (Courtesy of Ford Motor Co.)

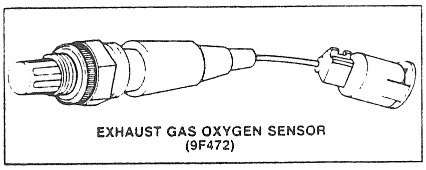


FIGURE 18-22
EGO sensor. (Courtesy of Ford Motor Co.)

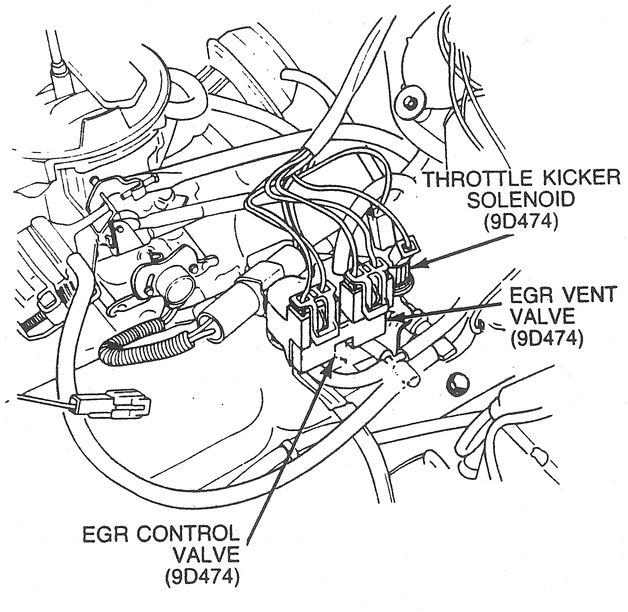


FIGURE 18-23
EGR and kicker solenoids. (Courtesy of Ford Motor Co.)

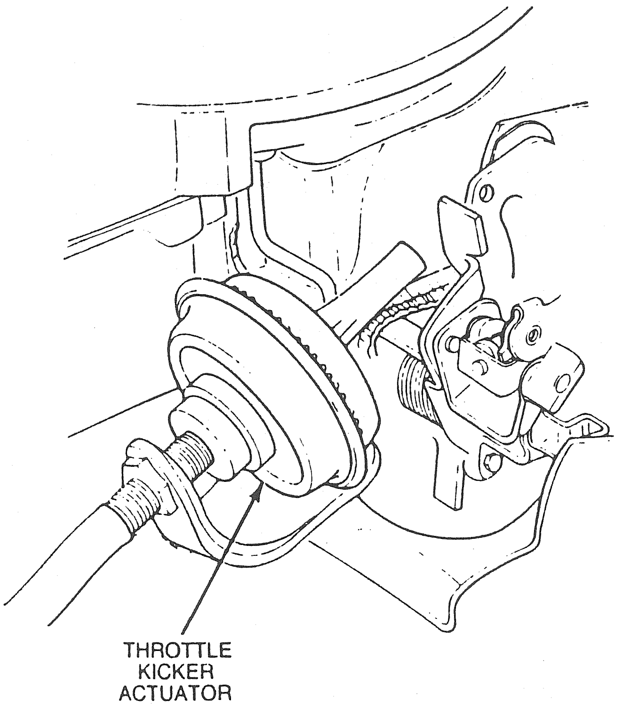


FIGURE 18-24
Throttle kicker actuator. (Courtesy of Ford Motor Co.)

of these solenoids are similar to the ones used on the EEC-I system. The main difference is that the EEC-II solenoids control vacuum instead of air pressure, as in the case of the EEC-I units.

Since the vent solenoid is normally open, its outlet port is open to the atmosphere when the unit is de-energized and closed when energized. The control solenoid is normally closed, which means its outlet port is closed when the unit is de-energized and open to engine vacuum when energized. Therefore, the control solenoid regulates the vacuum signal that acts on the EGR valve diaphragm. The other solenoid takes care of venting all or part of the vacuum trapped in the diaphragm and lines. By using both of these solenoids together, the microcomputer can provide the exact amount of EGR valve opening for a precise flow rate.

Throttle Kicker Solenoid and Actuator The EEC-II system has a *throttle kicker solenoid (TKS)* and *throttle kicker actuator* (Figs. 18-23 and 18-24). Both of these units work together to increase engine idle by opening the throttle plates. The microcomputer energizes the TKS whenever the air conditioner clutch is engaged, engine temperature is below or above a specified value, and the vehicle operates above a given altitude. The rest of the time, the TKS is deactivated.

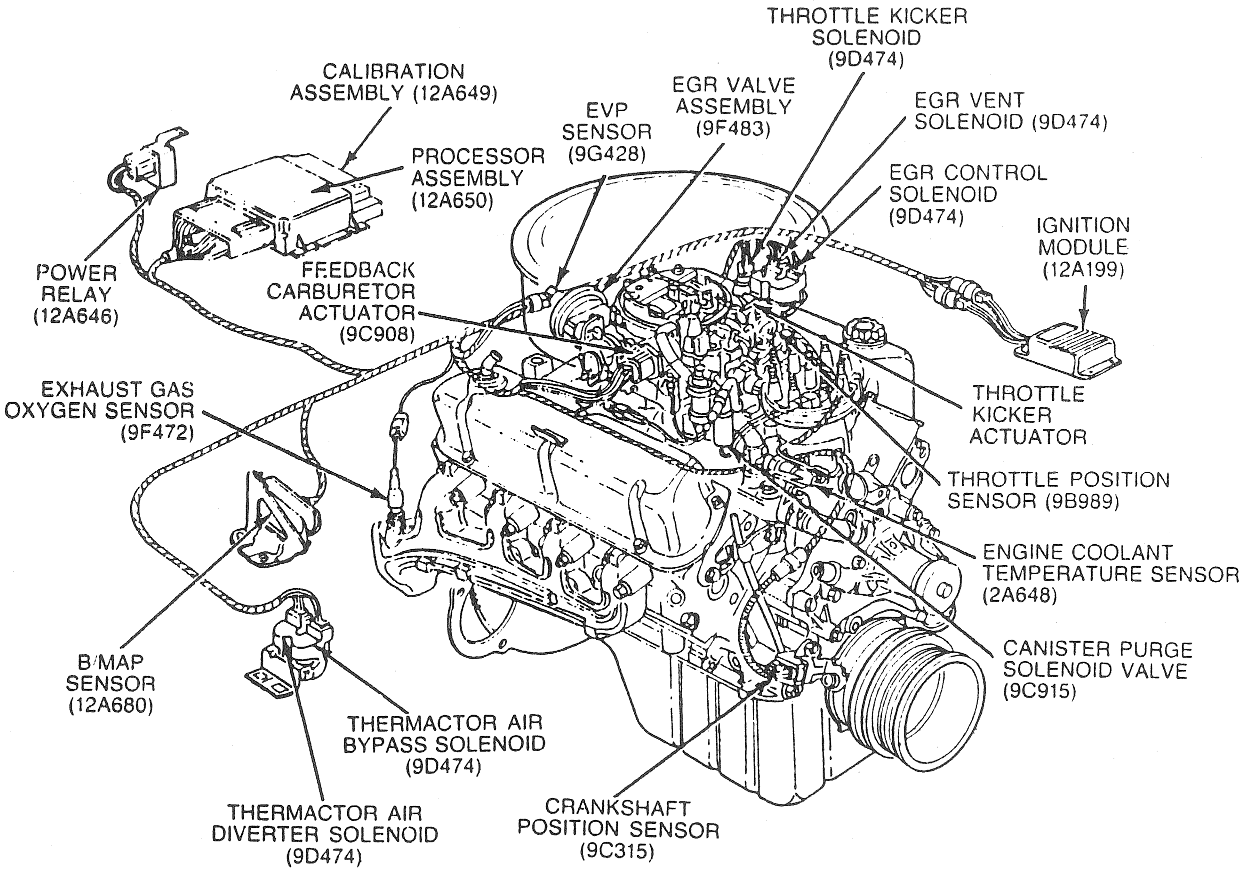


FIGURE 18-25
Location of Thermactor air solenoids. (Courtesy of Ford Motor Co.)

The kicker actuator consists of a spring-loaded diaphragm and plunger that operates inside a housing that threads onto a carburetor bracket. The end of the plunger contacts a throttle lever when the vacuum is supplied to its diaphragm.

When the microcomputer energizes the TKS, it opens and permits a vacuum signal to reach the actuator to increase the idle speed. When de-energized, the TKS shuts off and vents the actuator vacuum. Its plunger retracts, slowing idle speed back down. This action also permits the microcomputer to control engine idle speed and reduce the chance of engine dieseling after the engine is shut off.

Thermactor Air Control Solenoids. The EEC-II system needs two *Thermactor air control solenoids* instead of just the one used in the EEC-I system. The reason for this is that the vehicles using the EEC-II system also have dual-bed catalytic converters. These require a somewhat more complex control system for the purpose of switching injection air to either the upstream or downstream locations or to the atmosphere.

The two solenoids in Fig. 18-25 are mounted on the right fender apron. The solenoid closest to the rear is the *Thermactor air diverter (TAD)*. The forward one is the *Thermactor air bypass (TAB)* solenoid. These solenoids are used to regulate the flow of engine vacuum to the Thermactor air control and air bypass valves, depending on output demand from the microcomputer.

Canister Purge Solenoid. The *canister purge (CANP) solenoid* is a combination solenoid and valve that is located in the line between the intake manifold and the carbon canister (Fig. 18-26). This solenoid and valve control the flow of fuel vapors from the canister to the intake manifold during various phases of engine operation.

The microcomputer energizes the solenoid via an output signal. Remember, output signals trigger an output driver within the microcomputer that just completes a ground circuit for the actuator or solenoid. In any case, the actual periods when the CANP solenoid should be on and off are programmed into the microcomputer.

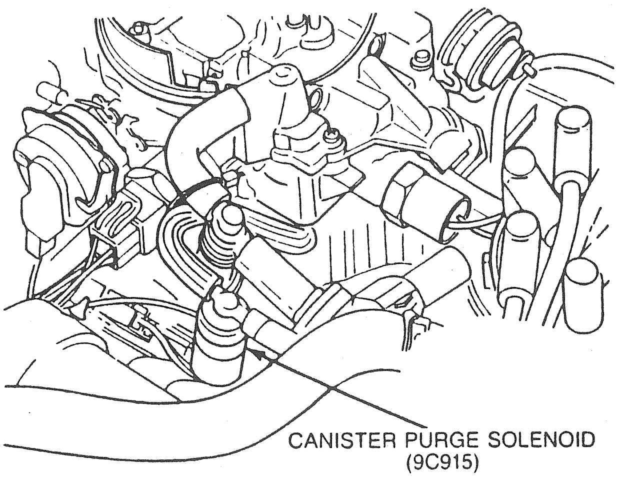


FIGURE 18-26
CANP solenoid valve. (Courtesy of Ford Motor Co.)

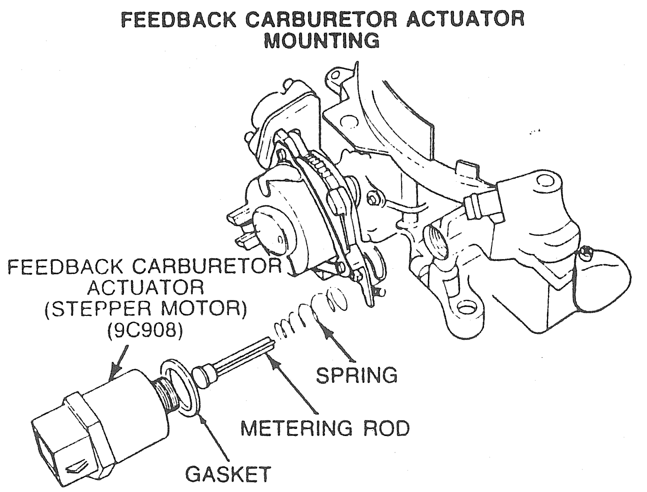


FIGURE 18-27
Feedback carburetor actuator. (Courtesy of Ford Motor Co.)

Feedback Carburetor Actuator. The *feedback carburetor actuator (FBCA)* is used to control the carburetor air/fuel ratio (Fig. 18-27). The FBCA is a stepper motor that mounts on the right side of the carburetor. Moreover, the FBCA provides 120 steps of air/fuel ratio adjustment within a 0.40-inch range of travel of the metering rod. The extended position of the rod supplies the richest air/fuel ratio.

The motor within the FBCA varies the position of the metering rod in the carburetor. This action regulates the amount of control vacuum exposed to the fuel bowl. The control vacuum lowers the amount of pressure in the fuel bowl, causing a leaner air/fuel mixture.

The FBCA motor has four windings. The microcomputer sequentially energizes the windings in order to obtain the necessary control of the metering rod. The microcomputer uses input from sensors such as the EGO, TP, and B/MAP to calculate the correct drive motor signals to maintain the desired air/fuel ratio for existing conditions. During engine cranking and immediately after start, for example, the microcomputer sets the FBCA at the initial calibration position. After this, the microcomputer adjusts FBCA position depending on calculations made from sensor inputs.

Ignition Module

With the exception of the ignition module, there were no changes to the ignition system used with the EEC-II system. For the EEC-II system, Ford introduced the Duraspark III ignition module.

Electronic Control Assembly

The ECA is the microcomputer for the EEC-II system and is similar in operation to that used on EEC-I. The EEC-II ECA also has two parts, the processor and calibration assembly, and mounts in the passenger compartment in the same general area as the EEC-I unit.

EEC-II Operation

With the engine operating, the EEC-II system uses input signals from seven sensors (Fig. 18-28), including the crankshaft position, throttle position, EGR valve position, barometric and manifold absolute pressure, engine coolant temperature, and exhaust gas oxygen.

These seven sensors constantly monitor their assigned functions and direct signals back to the ECA for analysis. The ECA, in turn, instantaneously analyzes these data and computes the correct amount of timing advance, EGR flow rate, air injection, air/fuel ratio, idle speed, and canister purging. Finally, the ECA sends output signals to activate the EGR control solenoids, Thermactor air control solenoids, canister purge solenoid, feedback carburetor actuator, and throttle kicker solenoid.

If a failure occurs in the ECA, the EEC-II system automatically enters an operating mode known as *limited operational strategy (LOS)*. In LOS, ECA output commands are cut off to EGR control solenoids, Thermactor air control solenoids, the canister purge solenoid, and the throttle kicker solenoid.

In addition, the spark advancement reverts to the initial ten degrees BTDC, regardless of sensor

1979 EEC-II 5.8L 351W FORD/MERCURY WIRING DIAGRAM

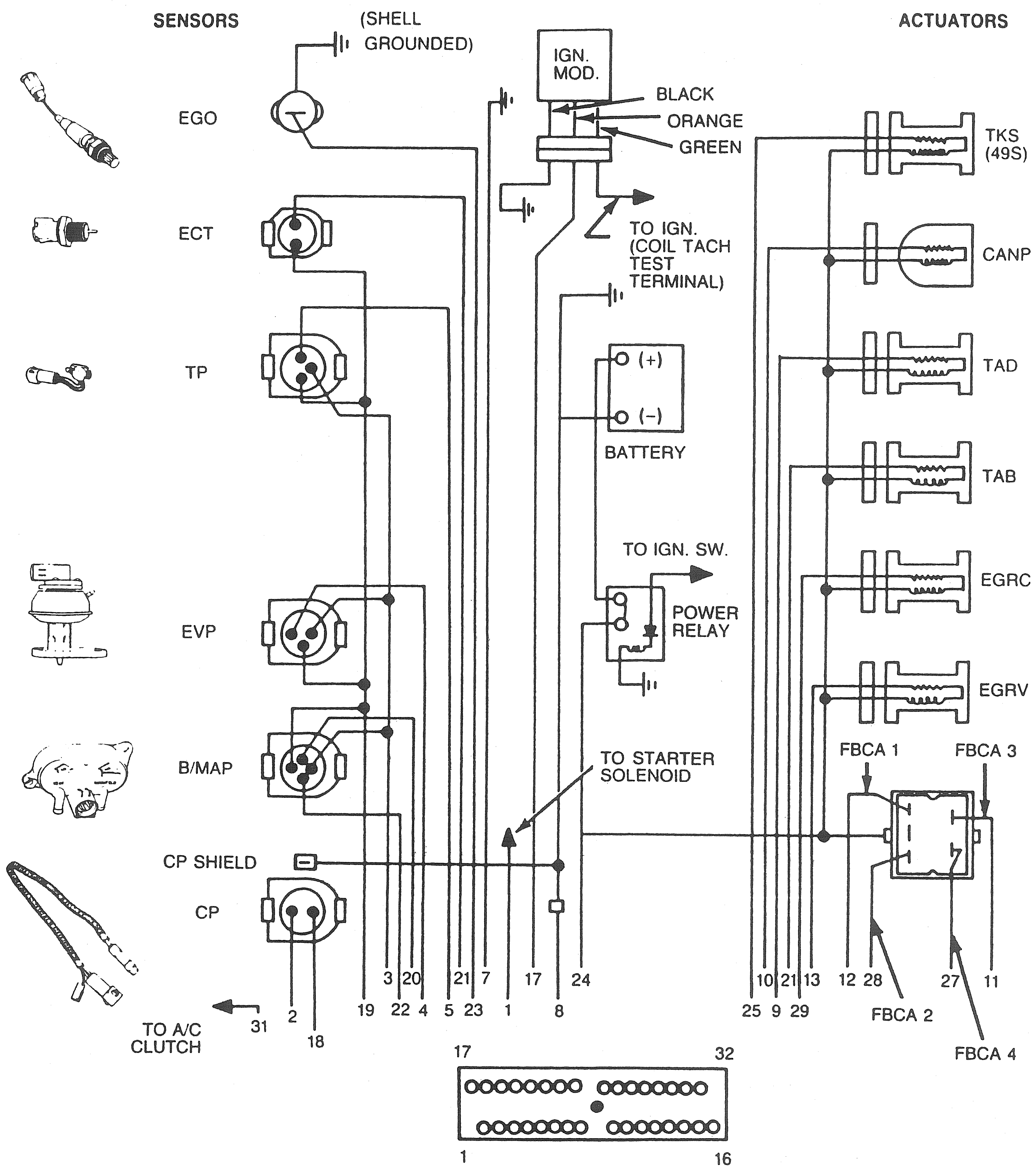


FIGURE 18-28
EEC-II operation. (Courtesy of Ford Motor Co.)

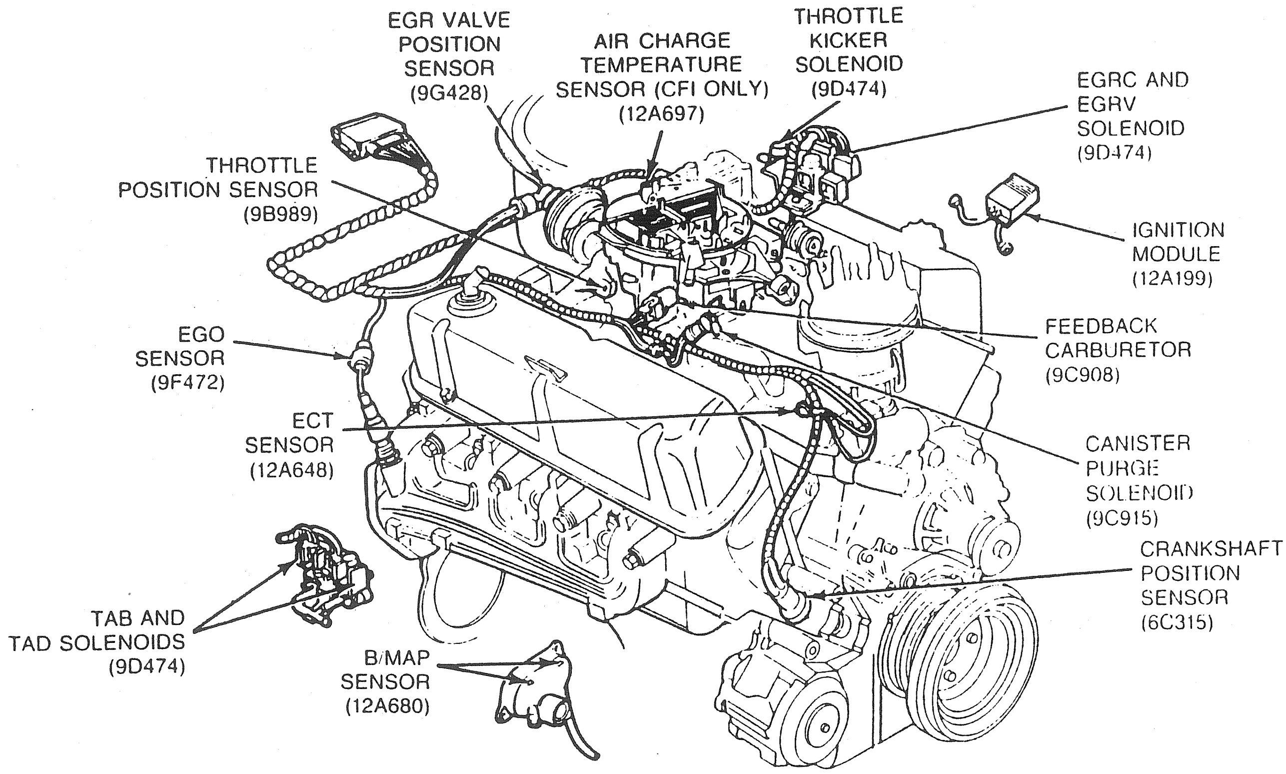


FIGURE 18-29
EEC-III system. (Courtesy of Ford Motor Co.)

input. Two windings of the feedback carburetor actuator are energized to hold the air/fuel ratio setting to what it was before the failure occurred. With these settings, the engine is operational but with reduced performance.

18-3 FORD EEC-III SYSTEM

In 1980, Ford Motor Company introduced the EEC-III system that was quite similar to EEC-II. The EEC-III system was modified in 1981 to include electronic fuel injection. Both the feedback carburetor and fuel injection versions of the system are found on vehicles through the 1983 model year. However, in 1984—the last year of its installation—EEC-III only appeared on fuel injected engines (Fig. 18-29).

System Inputs

Throttle Position. With the exception of an installation change to the throttle position (TP) sensor and the addition of an air charge temperature sensor, the remaining EEC-III sensors are the same as those found in EEC-II. On vehicles equipped with electronic fuel injection, the TP sensor attaches to the side of the engine fuel charging assembly and connects to the throttle shaft. The TP sensor is adjustable on both the feedback carburetor and CFI installations.

Air Charge Temperature Sensor. When the EEC-III system is used with electronic fuel injection, it requires an *air charge temperature (ACT) sensor* (Fig. 18-30). The ACT sensor measures the temperature of the air/fuel mixture in the seventh runner of the intake manifold.

The ACT sensor is a thermistor, so its resistance changes with increases or decreases in temperature. The microcomputer directs a reference voltage signal to the ACT sensor. The sensor's internal resistance then measures the air/fuel ratio temperature changes by the amount of reference voltage drop that results. The microcomputer monitors the voltage drop as an output ACT signal and uses it to adjust the air/fuel ratio for the various operating temperatures.

System Outputs

Feedback Carburetor Actuator. The system outputs for the EEC-III system are relatively unchanged from those used with EEC-II. Changes

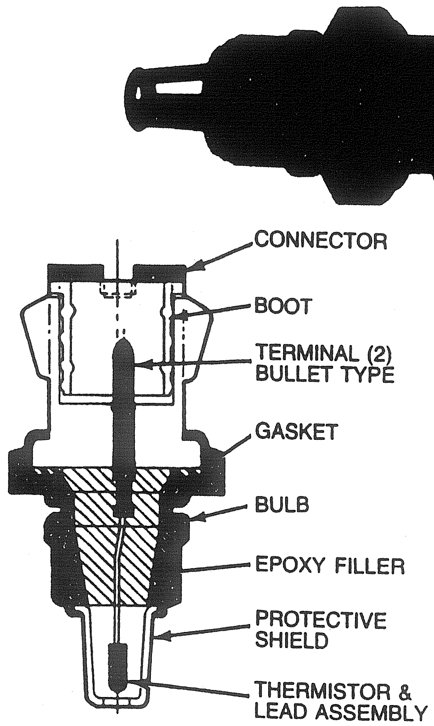


FIGURE 18-30
ACT sensor. (Courtesy of Ford Motor Co.)

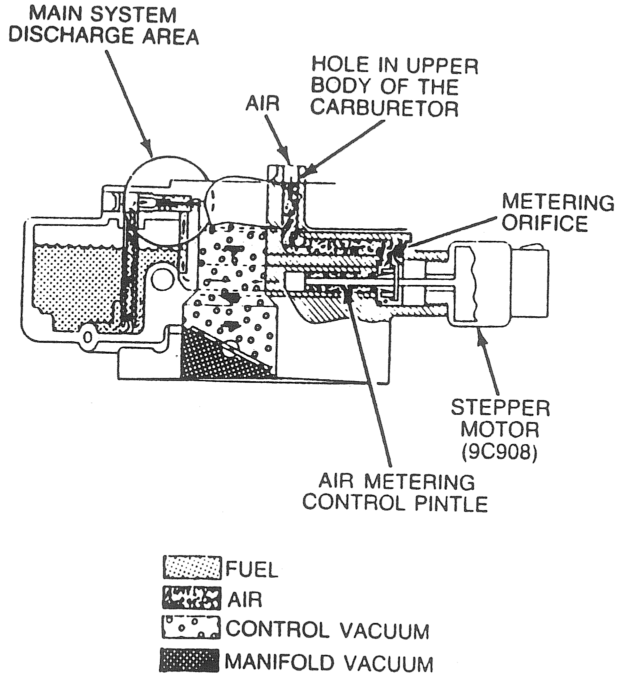


FIGURE 18-31
Stepper motor installation and operation. (Courtesy of Ford Motor Co.)

were made to the feedback carburetor actuator (FBCA) and fuel injection solenoids were added on central fuel injection (CFI) models.

For the EEC-III system, the FBCA is still energized by output signals from the microcomputer but operates on a different system than that used in EEC-II (Fig. 18-31). In the carburetor shown in the illustration, the FBCA stepper motor moves the air metering control pintle in the metering orifice. This varies the amount of air being metered into the main system discharge areas. The greater the amount of air, the leaner the air/fuel mixture.

A hole in the upper carburetor body casting allows air from beneath the air cleaner to be channeled into the system discharge area. This air lowers the metering signal to the main jets, thus altering the amount of flow.

Fuel Injector Solenoids. The fuel injection system used in EEC-III is commonly referred to as *central fuel injection (CFI)* because the fuel injectors are centrally located on the engine intake manifold (Fig. 18-32). The fuel injectors mount on the engine fuel charging assembly and meter the amount of fuel entering the manifold.

The *fuel injector solenoids* are part of the injector assemblies, which mount vertically above the throttle plates within the charging assembly. The solenoids are electro-mechanical devices that meter and atomize the fuel being delivered into the intake manifold (Fig. 18-33).

Since the injector pintle control orifice is fixed and fuel supply pressure is constant, fuel flow to the engine is regulated by how long the solenoid is energized, that is, its *pulse width.* The microcomputer controls the pulse width according to input signals received from the various engine sensors, which indicate the operating phase of the engine.

Electronic Control Assembly

The ECA or microcomputer for the EEC-III system operates similar to the EEC-II unit and consists of a processor and calibration assembly (Fig. 18-34). However, the EEC-III assembly has new circuitry to improve its control over emissions and fuel economy. In addition, on vehicles with CFI, the ECA is modified internally so it, instead of the feedback carburetor actuator, can control fuel injection solenoids.

EEC-III Operation

When operating, the EEC-III feedback carburetor system uses the same seven sensors that are found on EEC-II, while the CFI system requires eight (Figs. 18-35 and 18-36). These sensors include the

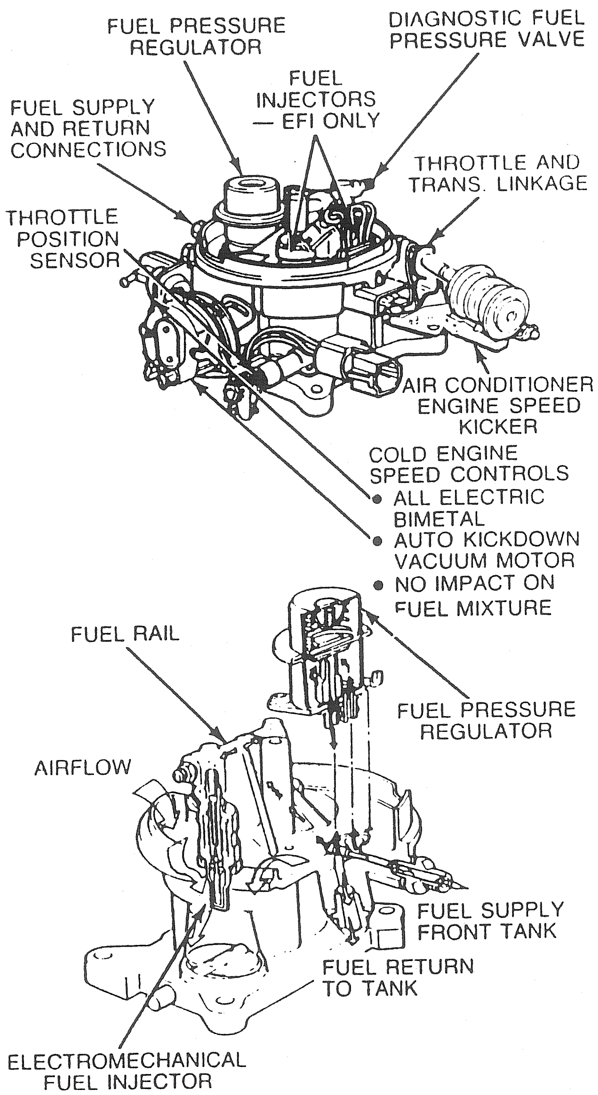


FIGURE 18–32
CFI assembly. (Courtesy of Ford Motor Co.)

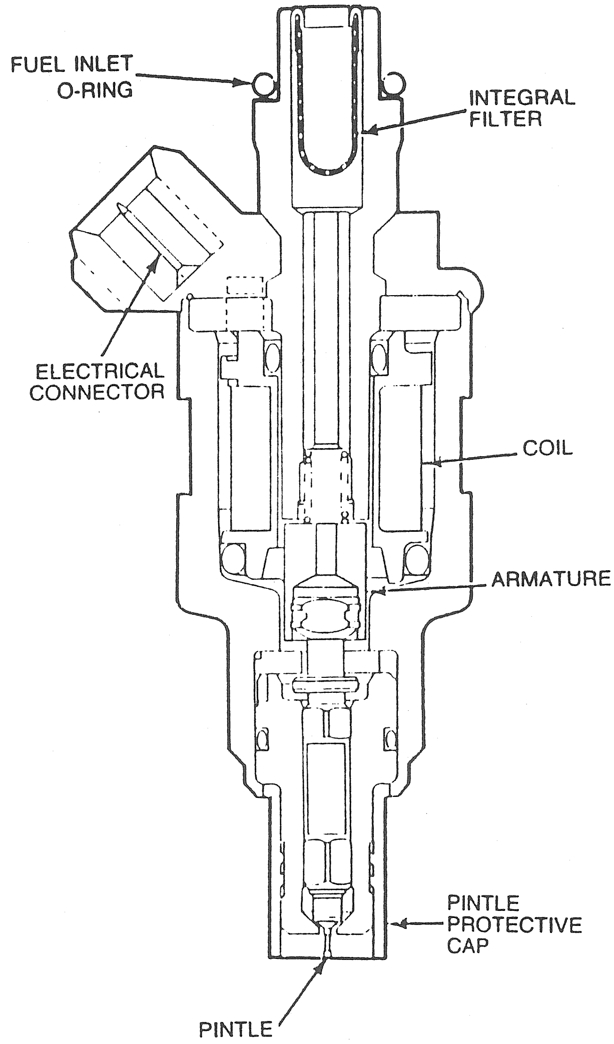


FIGURE 18–33
Injector solenoid. (Courtesy of Ford Motor Co.)

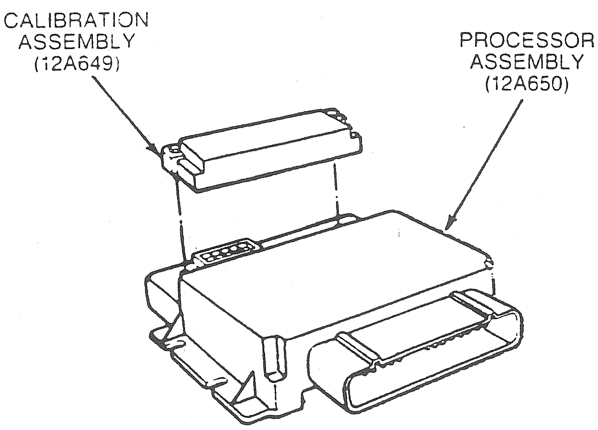


FIGURE 18–34
EEC-III electronic control assembly. (Courtesy of Ford Motor Co.)

crankshaft position, throttle position, EGR valve position, barometric and absolute pressure, engine coolant temperature, air charge temperature (used only on the CFI system), and exhaust gas oxygen.

The ECA continuously monitors the signals from these seven or eight engine sensors. It then analyzes the information and computes the proper amount of ignition timing, EGR flow, air injection, air/fuel ratio, engine idle, and canister purging. The ECA next sends output signal commands to the EGR solenoids, Thermactor solenoids, canister purge solenoid, feedback carburetor actuator or fuel injector solenoids, throttle kicker solenoid, and ignition module.

The ECA is designed to operate using three operating strategies: base engine, modulator, and lim-

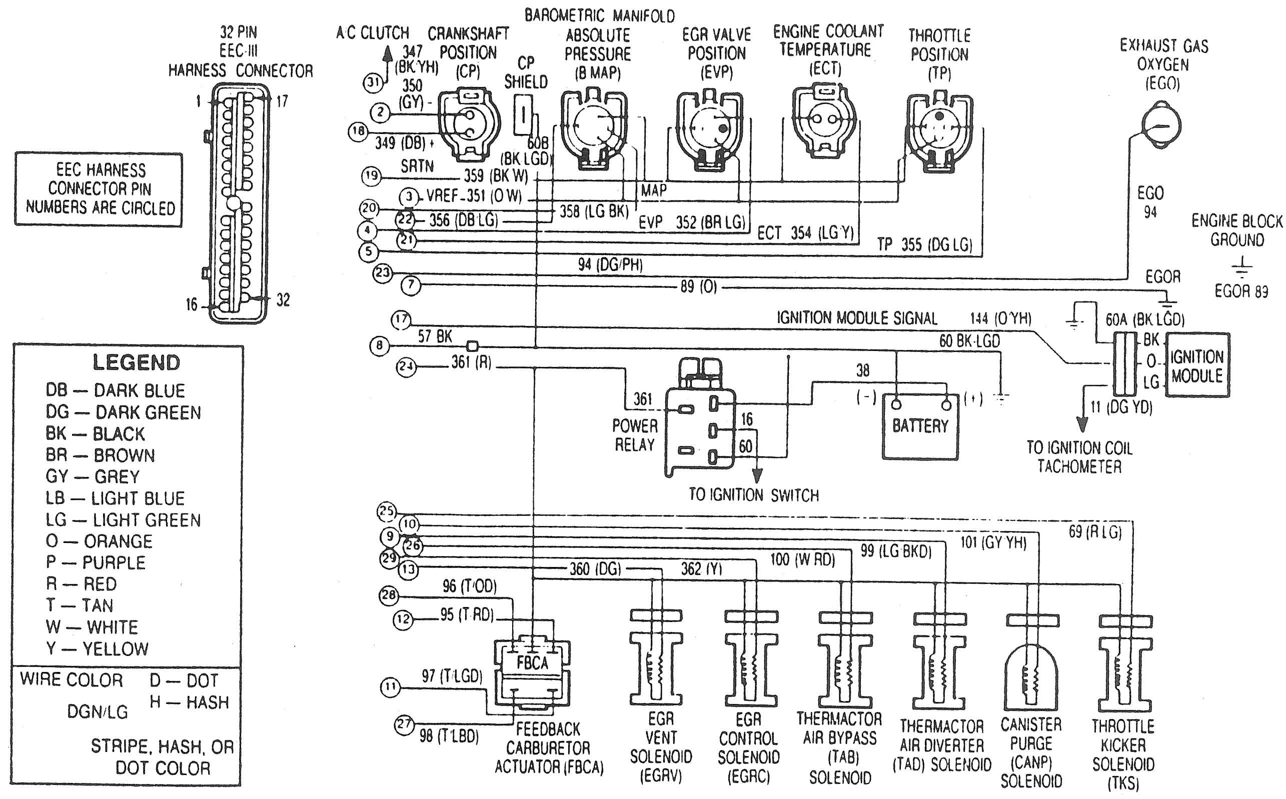


FIGURE 18–35
EEC-III FBC system operation. (Courtesy of Ford Motor Co.)

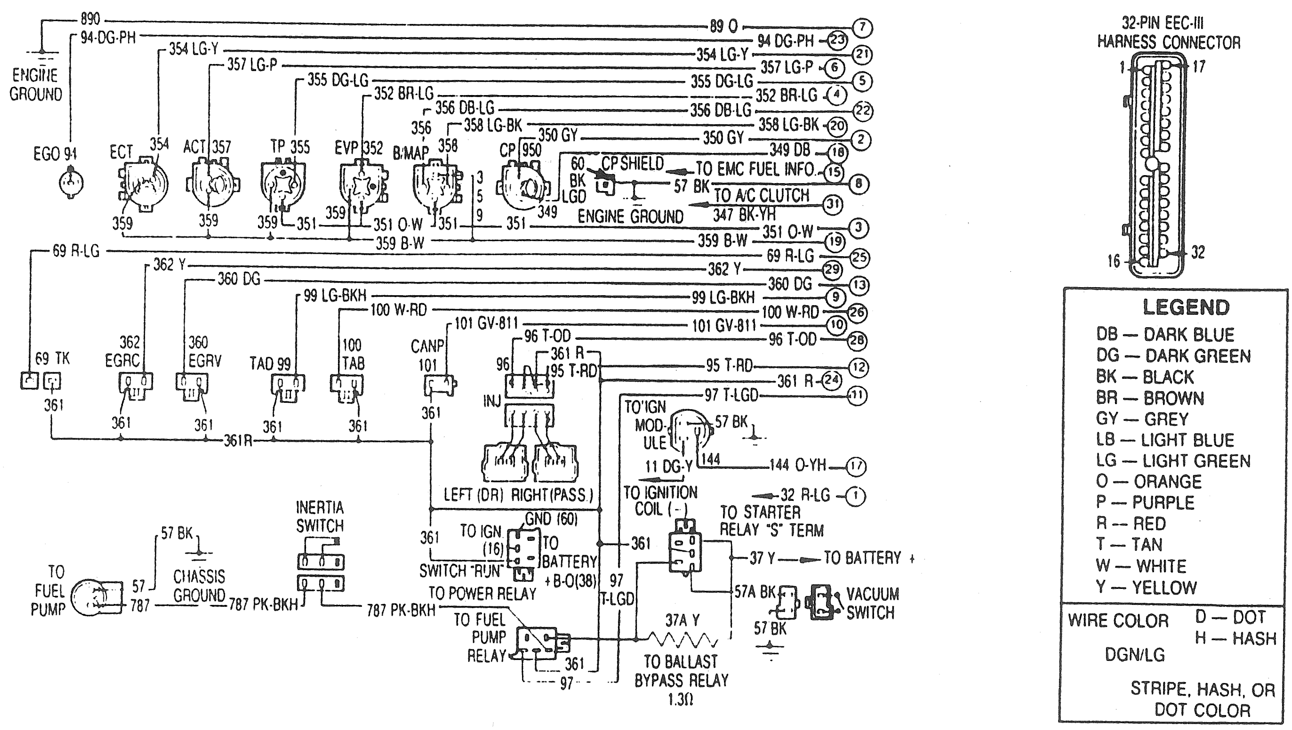


FIGURE 18–36
EEC-III CFI system operation. (Courtesy of Ford Motor Co.)

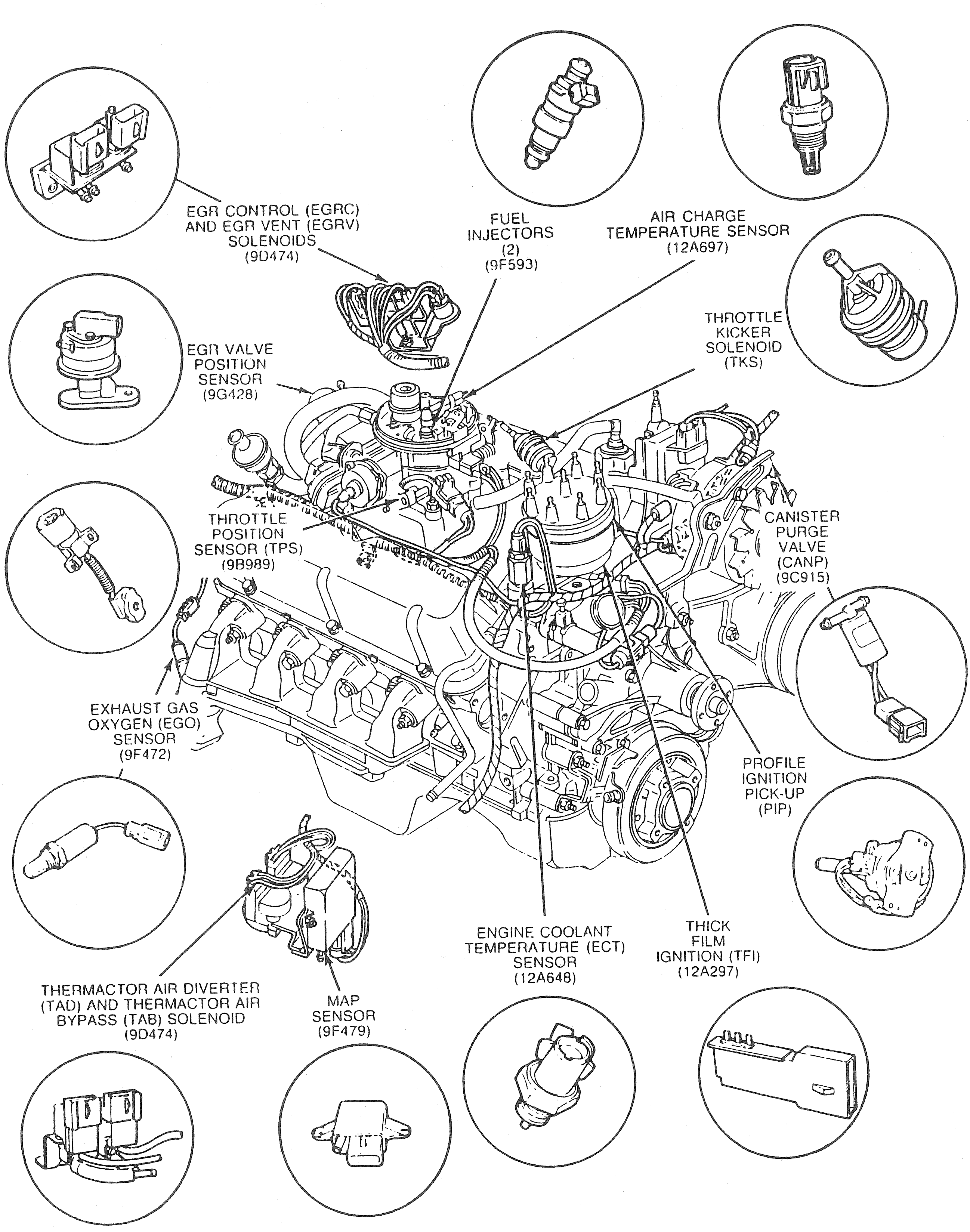


FIGURE 18–37
Typical EEC-IV system. (Courtesy of Ford Motor Co.)

ited operational. The EEC-III system operates using *base engine strategy* during normal city and highway driving. In order to control the wide range of conditions found during this kind of driving, the base strategy is further divided into the run-modes: crank, closed throttle, part throttle, and wide-open throttle.

Data from the engine sensors determine which mode the ECA will use. The ECA then operates within the proper mode to control the system output actuators according to calibration data stored in memory.

The EEC-III system enters the *modular strategy* during uncommon operating conditions, including operation with a cold or overheated engine or at high altitudes. The modular strategy built into the ECA modifies the base strategy to compensate for the unusual conditions.

The *limited operational strategy (LOS)* is about the same as that found in EEC-III. LOS permits a vehicle to operate safely in case of failure in the ECA. In LOS, the output command signals are cut off to the EGR solenoids, Thermactor solenoids, canister purge solenoid, and throttle kicker solenoid.

Moreover, if the vehicle has central fuel injection, the injector solenoids go to the maximum rich condition.

18-4 FORD EEC-IV SYSTEM

The EEC-IV system was introduced in 1983 on some Ford vehicles and is still in use today. The system works the same as the EEC-III in that it still controls the air/fuel ratio, emission systems, and vehicle driveability. However, EEC-IV uses a greater number of sensors because it has been used on carbureted, central, and multipoint fuel injection systems (Fig. 18-37).

System Inputs

Throttle Position Sensor. There are two different kinds of throttle position (TP) sensors used on EEC-IV systems, the rotary and linear. The location and operation of the *rotary throttle position sensors* found on the feedback and EFI engines are the same as those used on EEC-III. When the engine has multipoint fuel injection, the TP sensor is on the side of the throttle body, which mounts on the fuel charging assembly (Fig. 18-38).

The EEC-IV rotary TP sensors are not adjustable and require replacement if found out of specifi-

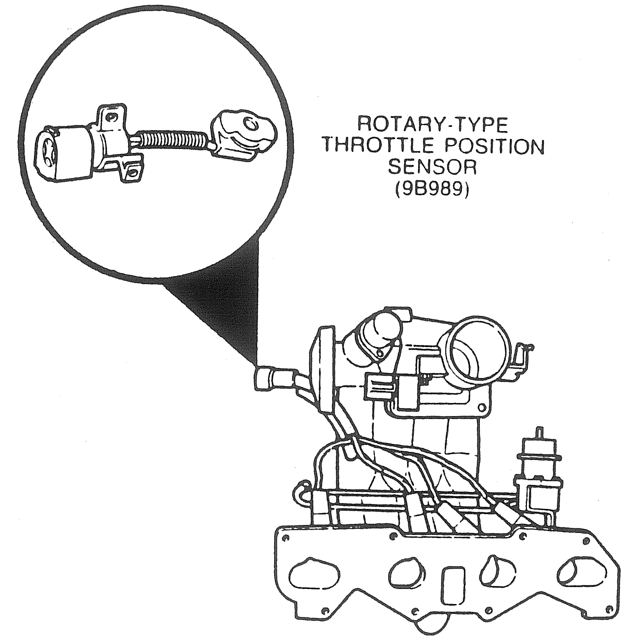


FIGURE 18-38
TP sensor used on multipoint fuel injection system. (Courtesy of Ford Motor Co.)

cations. The programming within the microcomputer compensates for any differences between original and replacement units.

The main difference between the rotary and *linear throttle position sensor* is not in function but rather in how each unit operates. The rotary unit, for instance, turns on an axis with the throttle shaft. The linear type has a plunger that rides on a cam that attaches to the throttle shaft (Fig. 18-39).

As the throttle is opened, the cam moves the plunger, which changes the voltage output from the sensor. This signal is correlated to throttle angle by the microcomputer. Finally, the linear sensor is adjustable by turning an adjustment screw on its housing.

EGR Position Sensor. The EGR position sensor for the EEC-IV system operates in the same manner as the one used on EEC-III. That is, the sensor monitors the position of the EGR valve pintle in order to keep the microcomputer informed of the exact amount of exhaust gas recirculation flow at all times.

Barometric Absolute Pressure Sensor. On EEC-IV systems, the function of the barometric and manifold absolute pressure combination sensor has been incorporated into one of two sensors, a barometric absolute pressure sensor and a manifold absolute

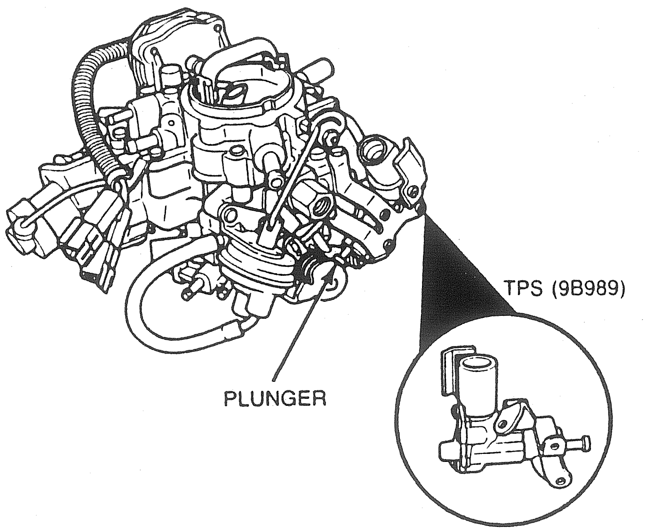


FIGURE 18-39
Linear TP sensor. (Courtesy of Ford Motor Co.)

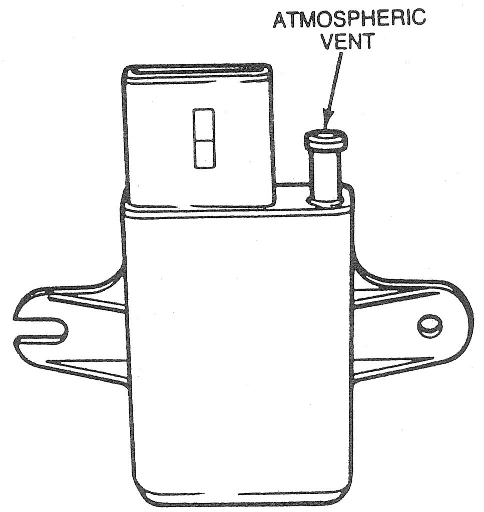


FIGURE 18-40
BAP sensor. (Courtesy of Ford Motor Co.)

pressure sensor. On certain applications, the microcomputer only needs barometric pressure data for altitude correction. On these configurations, a *barometric absolute pressure (BAP) sensor* is utilized (Fig. 18-40).

The BAP signals the microcomputer with barometric pressure data by means of a frequency instead of voltage. From this signal, the microcomputer adjusts the air/fuel ratio, idle speed, EGR flow, and ignition timing as a result of changes in barometric pressure.

Manifold Absolute Pressure Sensor. On other applications, the microcomputer only requires intake

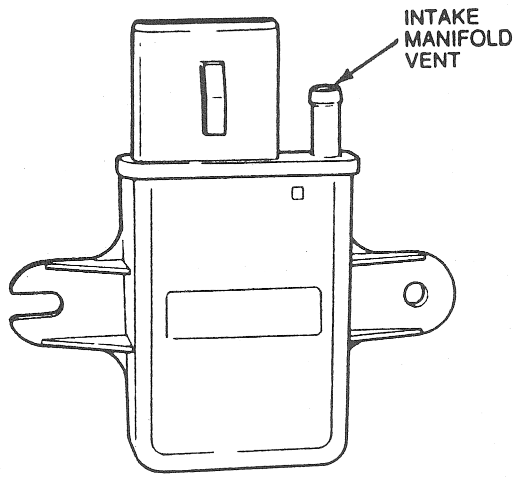


FIGURE 18-41
MAP sensor. (Courtesy of Ford Motor Co.)

manifold absolute pressure data. On these installations, a *manifold absolute pressure (MAP) sensor* is used (Fig. 18-41). The MAP sensor also measures the amount of manifold vacuum by means of a frequency signal in a similar way as the BAP sensor. The MAP signal informs the microcomputer under what load the engine is operating. Moreover, the MAP is used as a barometric sensor for altitude compensation when the key is in the on position and the engine is off. The MAP sensor updates this barometric data during every wide-open throttle (zero vacuum) condition.

Engine Coolant and Air Charge Temperature Sensors. The engine coolant temperature (ECT) and air charge temperature (ACT) sensors used on the EEC-IV system are the same as those used with EEC-III. The microcomputer uses the signal from the ECT to modify spark advance, EGR flow, and the air/fuel ratio in proportion to changes in coolant temperature.

The ACT signal only modifies the air/fuel ratio according to air/fuel or air temperature. When the ACT is in the intake manifold, it measures the temperature of the air/fuel ratio entering the engine. If in the air filter housing, it measures the temperature of the air entering the intake manifold.

Profile Ignition Pickup Sensor. The *profile ignition pickup (PIP) sensor* replaces the use of the crankshaft position sensor used on previous EEC applications (Fig. 18-42). The PIP sensor consists of a Hall-effect switch, magnet, and an armature with a certain number of windows and tabs. The field from the magnet is either permitted to reach or

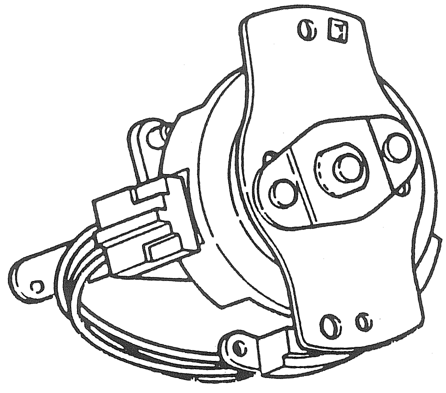


FIGURE 18-42
PIP sensor. (Courtesy of Ford Motor Co.)

blocked from reaching the Hall-effect switch by these windows and tabs, thus producing a signal. The microcomputer uses this signal for sensing crankshaft position and speed in order to compute the correct amount of spark advance and the timing of multipoint fuel injection.

Vane Air Temperature Sensor. On EEC-IV models with multipoint fuel injection, a *vane air temperature (VAT) sensor* is used (Fig. 18-43). The VAT sensor is one of two sensors located within the vane meter, which is located between the air filter and the intake manifold.

The VAT has a thermistor-type sensing element that monitors the temperature of the airflow through the vane meter. The resistance of the thermistor alters the strength of the reference voltage input signal with changes in air temperature. The microcomputer uses this as a signal to adjust the fuel flow to obtain the optimum air/fuel mixture.

Vane Airflow Sensor. The *vane airflow sensor* is the second sensing device located inside the vane meter (Fig. 18-44). Air moving through the air meter body moves a vane that is mounted on a pivot pin. The more air that is flowing, the farther the vane turns about the pivot point.

The air vane pivot pin connects to a potentiometer on top of the assembly. The potentiometer uses the reference voltage signal from the microcomputer to produce an output signal. The signal varies from zero to reference voltage, depending on the volume of air flow through the meter. A higher volume of air produces a greater voltage signal.

The microcomputer uses the signals from the VAF, VAT, and BAP sensors to determine the amount of fuel to inject into a given air mass flow. To do this, the microcomputer first has to convert the volume of air measured into an air mass value.

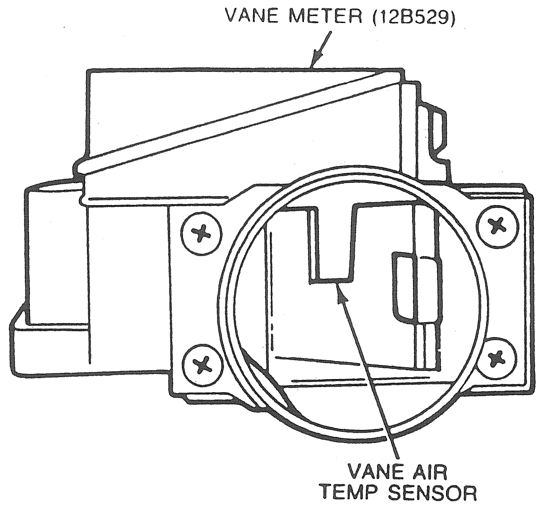


FIGURE 18-43
VAT sensor. (Courtesy of Ford Motor Co.)

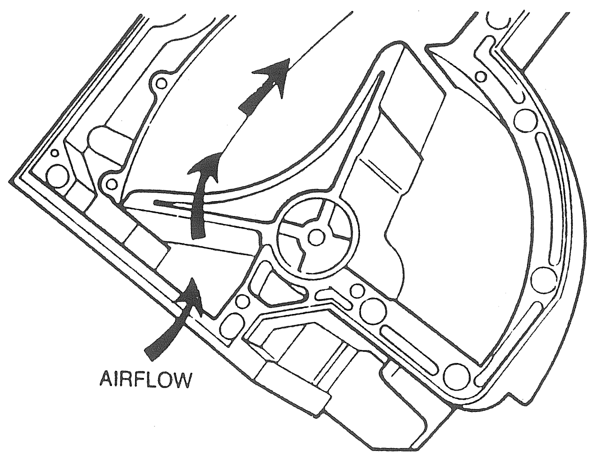


FIGURE 18-44
VAF sensor. (Courtesy of Ford Motor Co.)

However, the mass (weight) of a given volume of air varies with changes in barometric pressure and temperature. That is why the signals from both the VAT and BAP sensors are used in the calculations.

Idle Tracking Switch Some EEC-IV configurations use an *idle tracking switch (ITS)*. This switch is an integral part of the DC motor idle speed control (Fig. 18-45). The ITS provides a minimum voltage signal to the microcomputer when the throttle is open above idle. In this situation, the switch is closed because the throttle lever is not in contact with the DC motor idle speed control plunger. However, when the lever contacts the plunger at idle, the switch opens and the voltage signal to the microcomputer reaches its maximum value.

This switch and those described below receive

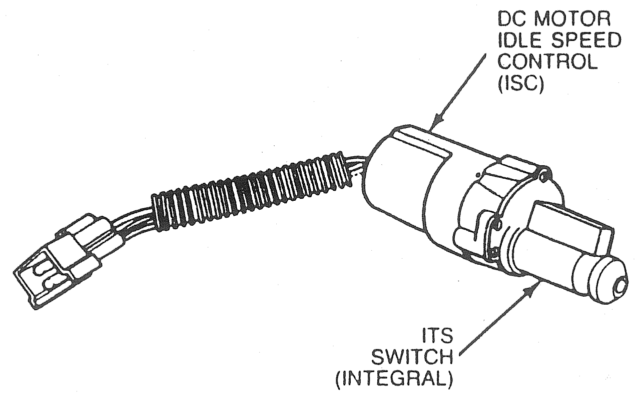


FIGURE 18-45
Idle tracking switch. (Courtesy of Ford Motor Co.)

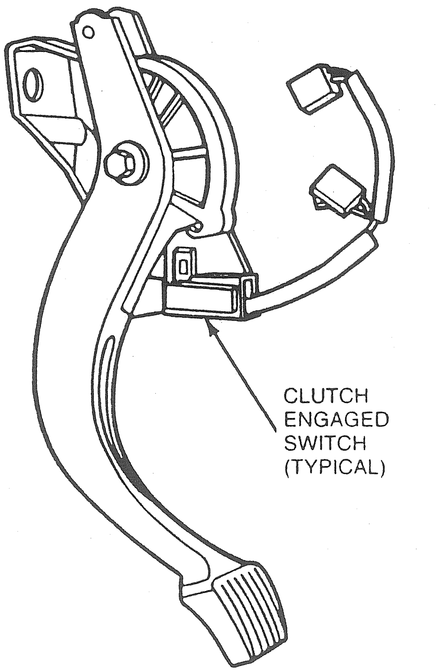


FIGURE 18-46
Clutch engaged switch. (Courtesy of Ford Motor Co.)

a reference voltage signal of five volts to one of their terminals. A special circuit from this terminal feeds back to the microcomputer input signal conditioners. The other switch terminal connects to ground through the processor. With this arrangement, the signal to the input conditioner will be reference voltage when the switch is open, but it will drop to less than one volt when the switch closes.

Basically, the switch provides two signals to the microcomputer. The first is a high reference voltage signal as the switch opens. The second is a weak signal when the switch closes.

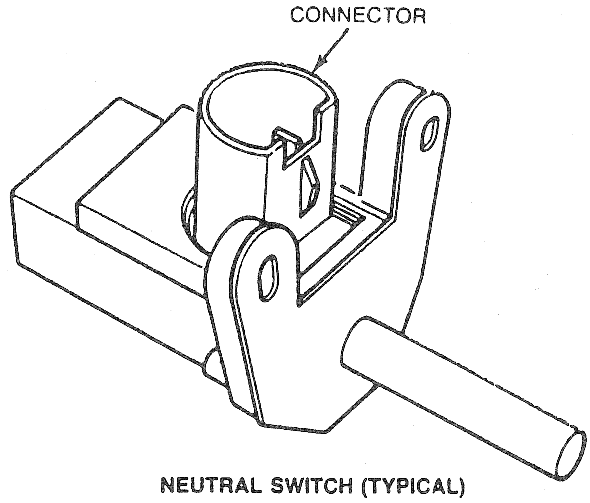


FIGURE 18-47
Transmission neutral switch. (Courtesy of Ford Motor Co.)

Brake and Power Steering Pressure Switch. A number of EEC-IV applications will use brake and power steering switches. The *brake on/off switch* signals the microcomputer when the brake is applied and released. These two signals allow the microcomputer to alter engine idle conditions. The microcomputer, for example, can alter the idle speed or turn off the air conditioner (A/C) compressor if an extended idle occurs with the brakes applied.

The *power steering pressure switch* signals the microcomputer when the power steering system pressure exceeds a specified amount or is normal. The microcomputer can then adjust the idle speed to compensate for the added load placed on the engine.

Clutch Engaged Switch. On vehicles with a manual transmission, a *clutch engaged switch* can be used (Fig. 18-46). This switch mounts on the clutch pedal lever and also has two positions, closed and open. When the clutch pedal is depressed, the switch closes and a low voltage signal is sent to the microcomputer. As the pedal is released, the switch opens, and the microcomputer receives a maximum voltage signal. The microcomputer uses the signals to determine whether there is no load (clutch disengages) or a load (clutch engaged) placed on the engine.

Transmission Neutral Switch. Another mechanism used on manual transmission vehicles to signal the microcomputer of an engine load condition is the *transmission neutral switch* (Fig. 18-47). This unit is a microswitch that closes only when the transmission is in neutral. This provides the low voltage signal to the microcomputer. In any other gear position, the switch is open and thus provides a

maximum signal to the input conditioners. The signals indicate whether there is no load (transmission not in gear) or a load (transmission in gear) placed on the engine.

Neutral Start Switch. On vehicles with automatic transmissions, a *neutral start switch* is utilized to indicate engine load conditions (Fig. 18-48). This switch mounts on the side of the transmission case and operates by means of the selector lever linkage.

The switch is open when the transmission is in drive or reverse. Thus, it provides a reference voltage signal to the input conditioners of the microcomputer.

In neutral or park, the switch is closed. As a result, the input signal drops to one volt or less. Using the two signals, the microcomputer adjusts engine idle speed for the load or no-load conditions.

In addition, a *neutral forcing relay* energizes in the START mode to provide a no-voltage signal on the reference line. The microcomputer reads this as a no-load condition on the engine and maintains a fast idle engine speed. The fast idle during starting improves the cold operating characteristics of the engine.

Without the relay, the neutral/drive input signal to the microcomputer in the START mode would remain high due to the battery voltage through the ignition switch. The microcomputer improperly interprets this as being a load condition, and the idle speed would be adjusted for that situation instead of the START mode.

Inferred Mileage Sensor. Late EEC-IV applications use an *inferred mileage sensor (IMS)*. This sensor monitors engine operating time using an *E-cell*. The E-cell actually measures a specific amount of ignition time, which equates to an estimated number of vehicle miles. Its function is to alert the microcomputer when the predetermined mileage has occurred so that it can adjust specific calibrations to compensate for engine wear.

A typical E-cell contains a silver cathode and a gold anode. Ignition voltage is applied to the E-cell through a resistor, and the resulting current flow through it controls a signal to the microcomputer. As the current passes through the cell, a chemical reaction takes place; that is, the silver on the cathode is attracted to the gold anode. After a certain period of time, the silver cathode is completely depleted and the circuit opens. How long this takes is controlled by the amount of current allowed to pass through the E-cell due to circuit resistance.

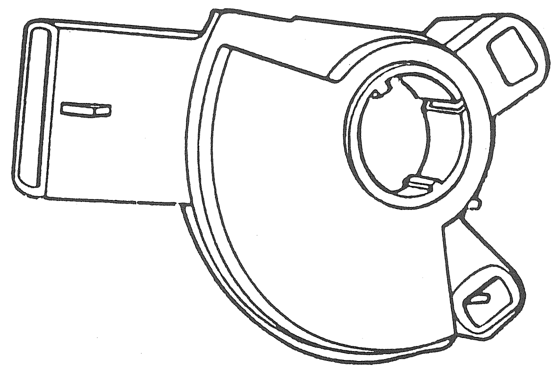


FIGURE 18-48
Neutral start switch. (Courtesy of Ford Motor Co.)

When the E-cell opens, a three-stage transistor is turned on to switch output. This causes the microcomputer to change its internal calibration for better control over emissions as more mileage is added to the engine.

Knock Sensor. The *knock sensor* used on certain EEC-IV configurations is a piezoelectric device that detects vibrations produced by engine knocking due to detonation. In operation, the quartz crystal within the sensor self-generates a signal to the microcomputer when it is placed under pressure by the vibrations. The intensity and duration of the vibrations determine the strength and continuance of the signal.

The microcomputer uses this signal to retard ignition timing when the engine detonates. This prevents any engine damage that could result from the detonation.

Ignition Diagnostic Monitor. The *ignition diagnostic monitor* compares the spark output of the ignition coil with the PIP signal to the microcomputer. The monitor causes a trouble code to show up during the system self-test if there is any problem with the signals.

System Outputs

EGR Control Solenoids The EEC-IV system can use two different EGR solenoid arrangements. In the first, two solenoids, which operate as in the EEC-III system, are utilized. In the second arrangement, a single EGR shutoff solenoid is used. This solenoid controls the vacuum-operating signal to the EGR valve itself. Depending on a signal from the microcomputer, the solenoid either turns on or off the EGR valve vacuum signal.

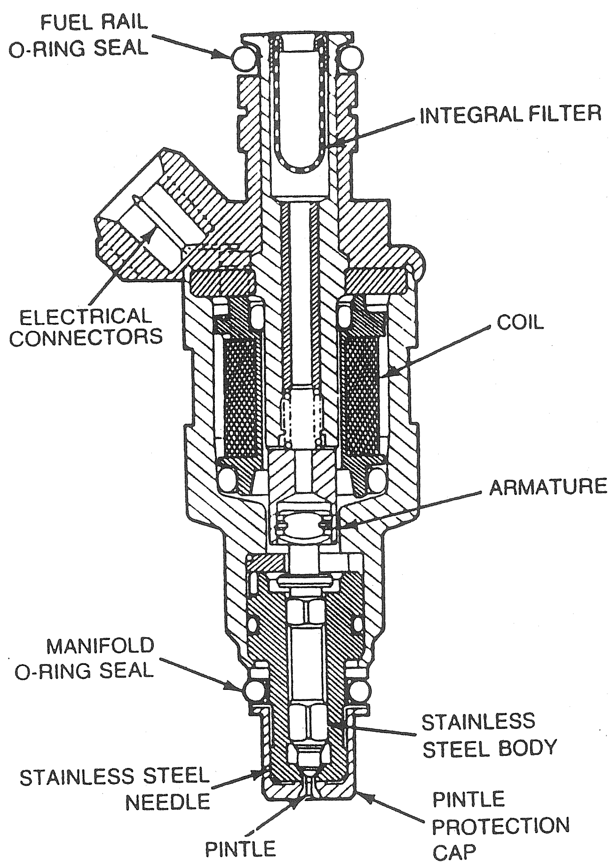


FIGURE 18-49
High-pressure multipoint fuel injector solenoid. (Courtesy of Ford Motor Co.)

Thermactor and Canister Purge Solenoids. The Thermactor air control solenoids and the canister purge solenoid operate in the same manner as those found on the EEC-III system. The Thermactor TAD solenoid controls the operation of the air diverter valve, while the TAB solenoid regulates the function of the air bypass valve. The canister purge valve is either opened or closed by a signal from the microcomputer.

Fuel Injector Solenoids. The EEC-IV system can use one of three different types of fuel injector solenoids. Two of these units, the *high pressure central and multipoint fuel injector solenoids,* operate the same as those found in the EEC-III system. The major differences between them are in the design of each unit's top section and their installed locations (see Figs. 18-33 and 18-49). In the high-pressure, CFI system, the solenoids mount vertically above the throttle plates. The multipoint injectors mount within the intake manifold, above each cylinder's intake valve.

All of these injectors are electro-mechanical devices that meter and atomize the fuel delivered into the engine. Metering is accomplished by controlling the length of time the microcomputer energizes the solenoid, that is, its pulse width. The microcomputer controls the pulse width according to the input signals received from the various engine sensors. Fuel atomization is accomplished by contouring the pintle at the point where the fuel enters the pintle area.

The other type of injector utilized is the *low-pressure solenoid.* This unit is found on the low-pressure CFI system (Fig. 18-50). This injector is also an electro-mechanical device that meters and atomizes the fuel. However, instead of using a pintle to control fuel flow, a ball is moved off its seat when the injector is energized by the microcomputer. This permits the fuel to flow from the spray nozzle.

Feedback Control Solenoid. There are two different types of carburetor feedback control systems used on EEC-IV vehicles, one using the feedback control solenoid and the other a duty-cycle solenoid. The *feedback control solenoid* is a pulsing unit that introduces fresh air from the air cleaner into the idle and main system vacuum passages of the carburetor. An electrical signal from the microcomputer activates the solenoid.

The amount of air the solenoid allows to enter a circuit depends on its *duty cycle.* During a given time period, a zero percent duty cycle closes the solenoid, and the carburetor goes to a maximum rich condition. On the other hand, a 100 percent duty cycle fully opens the solenoid, and the carburetor provides a maximum lean condition. A 50 percent duty cycle then means that the solenoid is fully open half of the interval period and closed the rest.

The feedback control solenoid is used on the YFA-IV and 2150-2V carburetors.

Duty-Cycle Solenoid. The second type of feedback control is the *duty-cycle solenoid* that is used on the 6149-IV carburetor (Fig. 18-51). This unit operates in much the same manner as the feedback solenoid but has a different mounting location and more port openings. The solenoid itself mounts on the firewall and has four hose fittings. The middle two are the fresh air and idle feedback bleed air ports. These are used to control the idle and off-idle air/fuel ratios by permitting air to enter the system.

The bleed port connects via a hose to a separate channel in the air horn of the carburetor, which conveys air into the idle circuit. When the microcomputer energizes the solenoid to open its valve, air en-

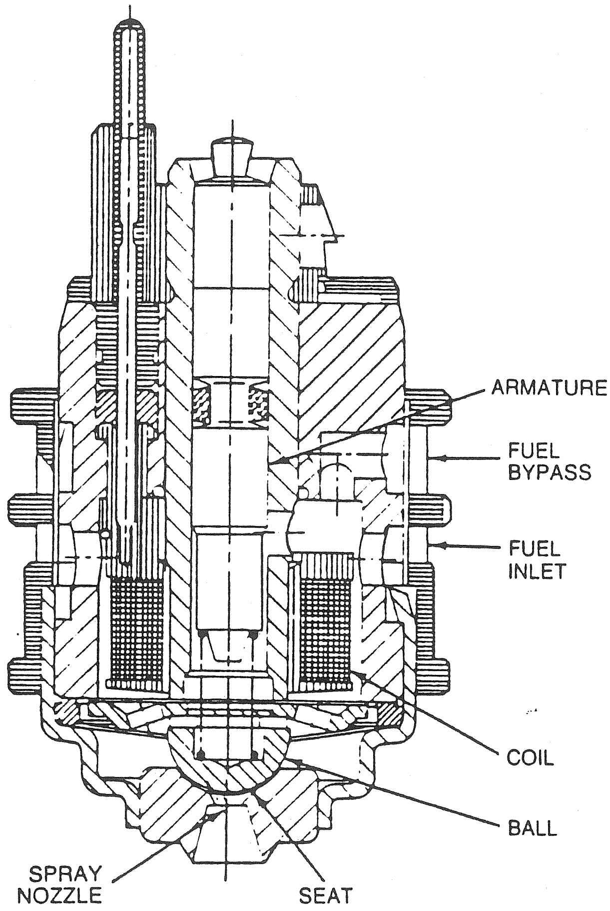


FIGURE 18-50
Low-pressure fuel injector solenoid. (Courtesy of Ford Motor Co.)

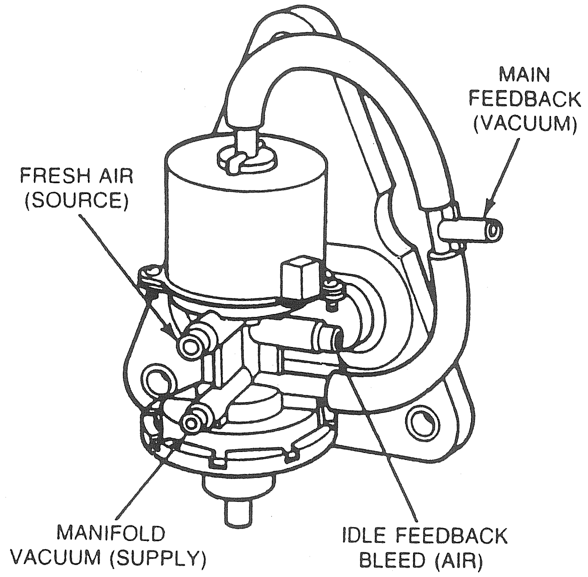


FIGURE 18-51
Duty-cycle solenoid. (Courtesy of Ford Motor Co.)

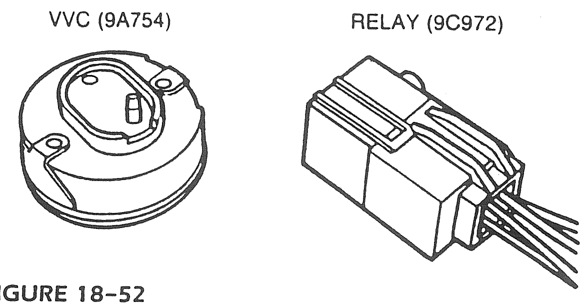


FIGURE 18-52
Variable voltage choke. (Courtesy of Ford Motor Co.)

ters the fresh air port and passes out the bleed port into the idle circuit, *when it is functioning,* to lean out the mixture.

The lower two ports are the manifold vacuum and main feedback. The feedback fitting via a hose supplies vacuum to a diaphragm-operated fuel control valve assembly inside the carburetor. This assembly resembles the power valve found in conventional carburetors. When the microcomputer energizes the solenoid, vacuum is supplied to the diaphragm assembly to lift it away from the spring-loaded control valve. This allows the valve to close and lean out the air/fuel ratio.

It is important to note that the solenoid, when energized by the microcomputer, supplies fresh air to the idle feedback and vacuum to the main feedback circuits at the same time. Since the carburetor idle and main systems operate at different periods, solenoid action has no effect on engine operation.

Variable Voltage Choke. Some EEC-IV vehicles have a *variable voltage choke* (Fig. 18-52). This unit slows down or speeds up the time the choke is acting, thus varying the percentage of its on-time. This system includes a choke cap, solid-state choke relay, and a microcomputer output signal. This signal is in the form of duty-cycle battery voltage.

At low temperatures, the microcomputer duty cycles the voltage to the choke every 2-1/2 seconds. As coolant and air temperatures go up, or after the engine has been running for a period of time, the percentage of the duty-cycle voltage to the choke increases to 100 percent. For example, at a 50°F (10°C) engine start-up, the choke is on about 20 percent of the time. However, at 80°F (27°C), the choke has a 100 percent duty cycle.

Temperature-Compensated Accelerator Pump Solenoid. The *temperature-compensated accelerator pump solenoid* is similar to the throttle kicker solenoid. The solenoid valve is used in conjunction with a temperature-compensated system and was devel-

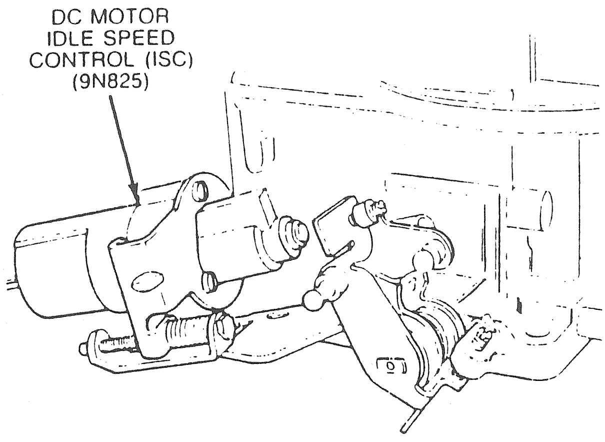


FIGURE 18-53
ISC motor. (Courtesy of Ford Motor Co.)

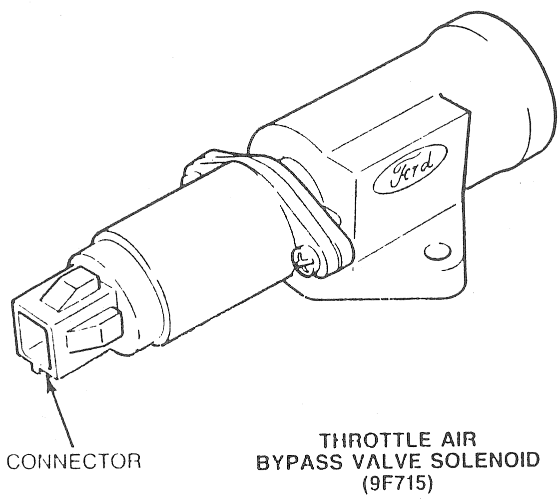


FIGURE 18-54
Throttle air bypass valve solenoid. (Courtesy of Ford Motor Co.)

oped to provide better control over the volume of cold and warm engine accelerator pump discharge. The system delivers a large volume of fuel when the engine is cold and a lesser amount when it is warmed up. The amount of fuel delivered during warm engine operation depends on the rate at which the accelerator pedal is opened—a fast opening results in a reduced delivery, a slow opening in an increased delivery.

The solenoid controls the operation of a diaphragm-operated ball check valve that indexes over a bypass bleed between the accelerator pump output circuit and the float bowl. When the microcomputer energizes the solenoid at about 80°F (35°C), vacuum is applied to the diaphragm. The diaphragm moves and relieves spring tension on the check valve. As a result, the accelerator pump functions as a rate-sensitive device, bypassing a portion of the fuel back to the float bowl during a fast opening of the accelerator pedal.

Throttle Kicker Solenoid. The throttle kicker solenoid (TKS) and the actuator used on the EEC-IV system operate in the same manner as those found on EEC-III vehicles. The kicker system is utilized on both carburetor and high-pressure CFI systems, depending on engine application, to control engine idle speed. The microcomputer energizes the TKS during A/C compressor clutch engagement, whenever the engine temperature is below or above a specified value, and when the vehicle is operating above a given altitude.

DC Motor Idle Speed Control. In place of the kicker system, some EEC-IV systems use the *DC motor idle speed control (ISC)* (Fig. 18-53). The ISC is an electro-mechanical device controlled by the microcomputer. The unit incorporates a DC motor that positions the throttle on carburetor systems and both high- and low-pressure CFI systems.

The microcomputer electrically controls the ISC motor operation, depending on engine operating conditions. For example, when the engine is shut off, the ISC plunger is backed off, closing the throttle to prevent dieseling. After the engine stops running, the ISC plunger then extends to its maximum length for restart.

On restart, the DC motor again retracts to hold engine speed to the rpm controlled by coolant temperature. As the engine warms up, the plunger continues to retract until the engine reaches hot curb idle.

During cruise operation, the ISC plunger extends to catch the throttle as it closes. In this way, the unit acts as a dashpot. Finally, the ISC also extends somewhat to adjust engine idle speed to compensate for a tight new engine, high altitude, or cold weather conditions.

Throttle Air Bypass Valve Solenoid. The *throttle air bypass valve solenoid* (Fig. 18-54) is used on EEC-IV systems with multipoint fuel injection. The valve solenoid is controlled by the microcomputer and regulates the engine idle speed, both warm and cold, and takes over the function of the choke's fast idle cam, the kicker system, ISC motor, or dashpot.

The valve solenoid may be attached to either the throttle body or the air cleaner, depending on ap-

plication. In either case, the device controls a given amount of airflow, which bypasses the throttle plates.

Turbocharger Boost Control Solenoid. In certain EEC-IV applications with turbocharged engines, a *turbocharger boost control solenoid* is used (Fig. 18-55). This solenoid is part of a system designed to provide electronic variable control of turbocharger operation. To perform this function, the control system provides regulation of the wastegate actuator signal, thus permitting between 10 psi (69 kPa) and about 15 psi (103 kPa) of turbo boost pressure.

The turbocharger boost control solenoid is installed between the wastegate actuator and the crankcase vent tube. This normally closed solenoid, when energized by the microcomputer, opens to permit boost pressure from the turbocharger compressor outlet to bleed through the solenoid and back into the compressor inlet.

Without the boost control solenoid, the wastegate would always open at about 10 psi (69 kPa). However, during boost control, the microcomputer opens and closes the solenoid at 40 cycles per second (40 hertz). This action permits the boost pressure to increase up to as high as approximately 15 psi (102 kPa). The amount of boost pressure depends on engine requirements, as determined by the microcomputer.

Wide-Open Throttle A/C Shutoff Relay. Certain EEC-IV engine applications use a *wide-open throttle A/C shutoff relay.* This relay system removes the added load of the A/C compressor from the engine for increased power.

In this system, the microcomputer controls the operation of a normally closed relay that is in line with the A/C compressor clutch (Fig. 18-56). To do so, the microcomputer provides a ground to the relay to energize its coil to open the relay points. This breaks the circuit to the A/C compressor clutch.

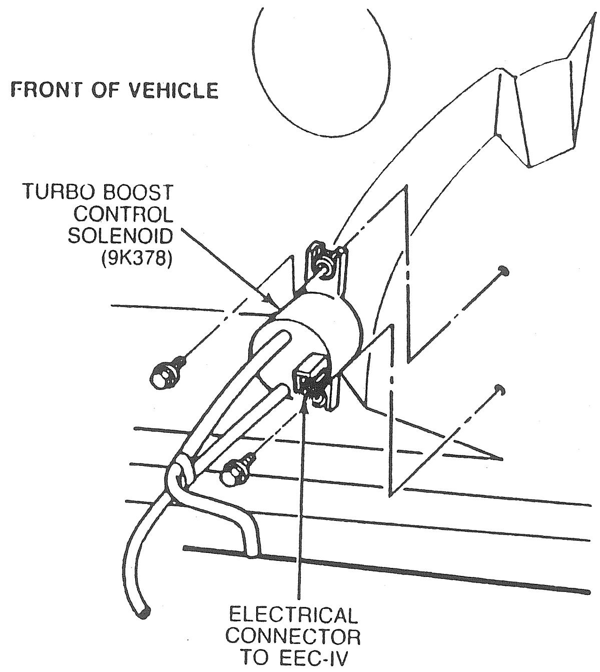


FIGURE 18-55
Turbocharger boost control solenoid. (Courtesy of Ford Motor Co.)

A/C Cooling Fan Controller Module. The *A/C cooling fan controller module* is used on some EEC-IV configurations to control the operation of the air conditioning compressor and engine cooling fan (Fig. 18-57). The module itself receives input from the microcomputer, coolant temperature switch, and the stoplight switch. The module, in turn, provides output signals to control the operation of the A/C compressor clutch and the engine cooling fan.

The signal for energizing the A/C compressor comes through the clutch cycling pressure switch to the module. The module then applies the operating voltage to the clutch. However, the microcomputer applies an input to the module that breaks the signal to the clutch at wide-open throttle. The same signal

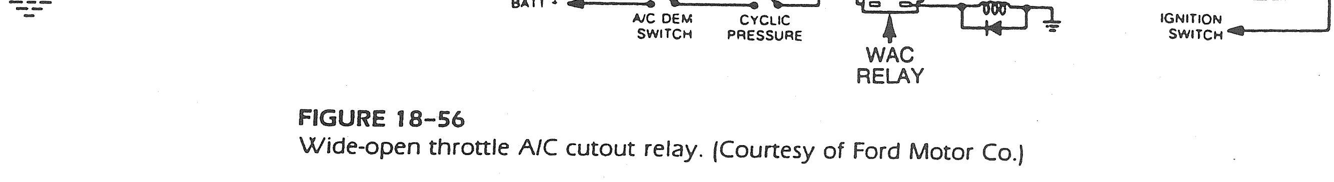


FIGURE 18-56
Wide-open throttle A/C cutout relay. (Courtesy of Ford Motor Co.)

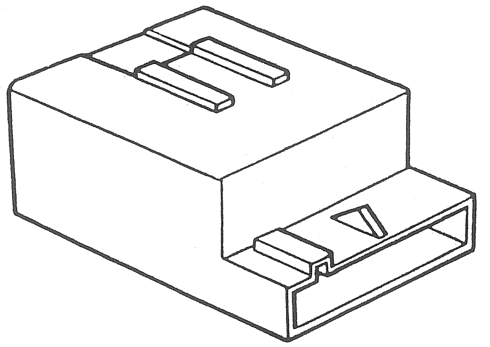


FIGURE 18-57
A/C cooling fan controller module. (Courtesy of Ford Motor Co.)

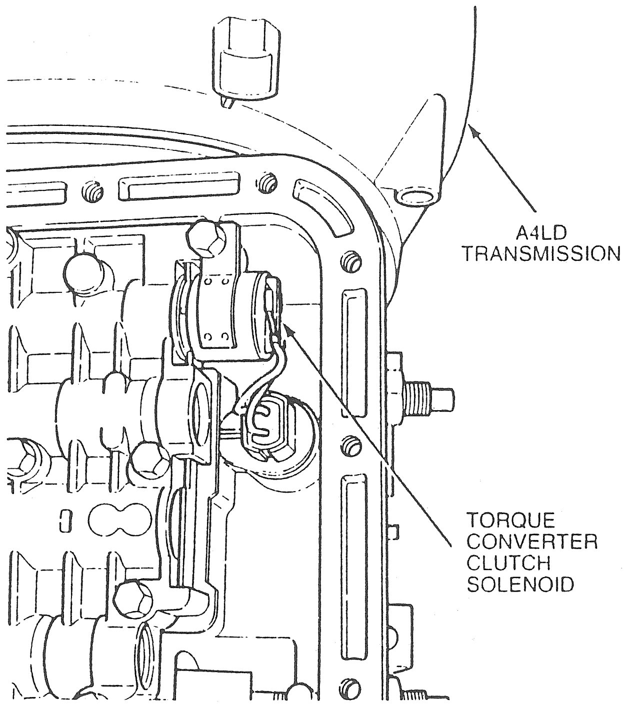


FIGURE 18-58
Torque converter clutch solenoid. (Courtesy of Ford Motor Co.)

also de-energizes the fan motor if the engine coolant temperature is below 221°F (105°C).

The engine coolant temperature switch provides a ground signal to the module if engine temperature exceeds 221°F (105°C). This ground overrides the microcomputer wide-open throttle signal and thus prevents the engine cooling fan from shutting off.

The microcomputer also has a time-out feature for the wide-open throttle signal. After about 30 seconds, the wide-open throttle signal is stopped, whether the wide-open throttle condition has ended or not. However, recycling from wide-open throttle and back again will shut off the A/C compressor clutch for another 30 seconds.

Stepping on the brake also provides a cut-off signal to the A/C clutch and the cooling fan for about three to five seconds on vehicles equipped with automatic transmissions and power brakes. This is accomplished by applying battery voltage through the stoplight switch to the controller module.

Torque Converter Clutch Solenoid. The *torque converter clutch (TCC)* or *converter clutch override (CCC) solenoid,* as it is sometimes called, is used on EEC-IV vehicles with the A4LD automatic transmission. The microcomputer energizes this solenoid (Fig. 18-58) when certain engine rpm and vehicle speed conditions have been met.

When the solenoid energizes, transmission fluid flows into passages in the torque converter, allowing it to lock up. This provides a direct connection between the engine and transmission when it is operating in third or fourth gear. This action is similar to the direct connection made possible by the friction clutch used with manual transmissions or transaxles.

Before the microcomputer will energize the solenoid, the following conditions must be met. The engine must be at normal operating temperature. The engine must be at the correct rpm and under low-load conditions. The correct vehicle speed must be obtained.

The microcomputer de-energizes the solenoid when the above conditions are not met and also when the stoplight switch is closed and when the TP sensor indicates the engine is operating at wide-open throttle.

Shift Indicator Lamp. The *shift indicator lamp* is found on some EEC-IV systems with manual transmissions. The light visually indicates to the operator when to upshift to the next highest gear ratio in order to obtain the best fuel economy.

The shift indicator lamp system incorporates the following features. The system is controlled by such factors as engine speed, vacuum, and coolant temperature. An indicator lamp on the instrument panel glows to show the shift points. A time delay prevents the lamp from flickering on when shifting or engaging the clutch after the rpm and vacuum set points are met. A top gear lockout mechanism prevents the lamp from burning when the vehicle is in the highest gear ratio. Coolant temperature delays

the operation of the indicator light when the engine is cold.

Ignition Module

A *TFI-IV (thick-film integrated) ignition system and module* are used with the EEC-IV system. The module (Fig. 18-59) is inside a molded thermoplastic housing that mounts on the distributor housing. The module features a push-start mode of operation. This allows push-starting a vehicle with a manual transmission should it become necessary.

Since the TFI-IV distributor has no vacuum or centrifugal advance mechanism, the microcomputer must control ignition timing during different operating conditions. The microcomputer accomplishes this by signaling the ignition module when to open the primary circuit and fire the spark plugs. The microcomputer circuit that provides the signal is known as the *spark output (SPOUT)* circuit.

ECA

The microcomputer for the EEC-IV system is the *electronic control assembly (ECA)*. This unit (Fig. 18-60) operates similarly to the ECA found in the EEC-III system. However, its circuits have been changed to improve control over emissions and fuel economy and, on some applications, to regulate multipoint fuel injection.

The EEC-IV electronic control assembly also has *keep-alive memory*, which is an advancement over the other EEC systems. The ECA now retains intermittent trouble codes, stored within the last 20 restarts. In other words, with this system, the memory is not erased when the key is turned off. These stored trouble codes are a tremendous help to the technician when diagnosing the EEC-IV system.

Note: The keep-alive memory function was not incorporated into the first release of EEC-IV on the 1.6-liter EFI engine.

There are some other differences between the EEC-IV and previous EEC systems. For example, the calibration module is now located inside the assembly. In addition, some early 1983 EEC-IV harness connectors are the unique, edge-card type rather than the pin and socket design. Finally, the EEC-IV's ECA sends out a five-volt reference voltage signal instead of the nine-volt signal sent out by the previous assemblies.

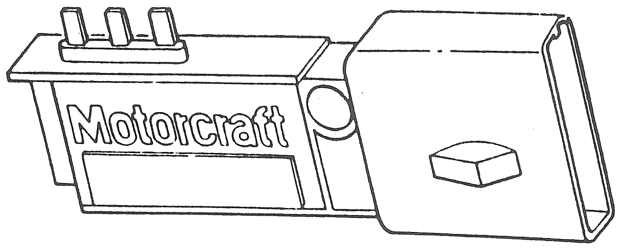


FIGURE 18-59
TFI-IV ignition module. (Courtesy of Ford Motor Co.)

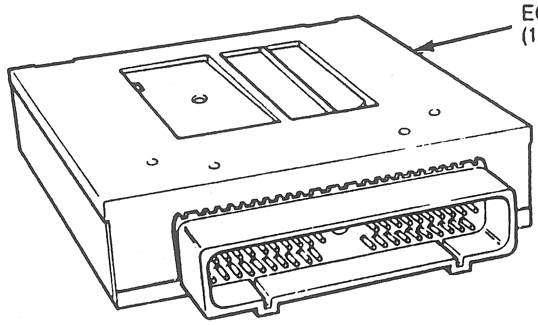


FIGURE 18-60
EEC-IV electronic control assembly. (Courtesy of Ford Motor Co.)

EEC-IV System Operation

In operation, the EEC-IV system uses a large number of sensors to provide data to the ECA (Fig. 18-61). However, not all of these sensors are found on all engine applications. The sensors that may be found on the different variations of the EEC-IV system include throttle position, EGR valve position, barometric and manifold absolute pressure, engine coolant temperature, air charge temperature, exhaust gas oxygen, profile ignition pickup, vane air temperature, vane airflow, idle tracking switch, neutral start switch, inferred mileage, knock, ignition diagnostic monitor, clutch engaged switch, transmission neutral switch, brake on/off switch, and power steering pressure switch.

The ECA constantly monitors the signals from the installed system sensors and then compares the input data against that programmed into memory. The ECA next computes the correct amount of ignition timing, EGR flow, Thermactor system operation, idle speed, air/fuel ratio, and canister purging. Finally, the ECA sends command signals to its output drivers to energize the following actuators: EGR control, vent, or shutoff solenoids; Thermactor air diverter and bypass solenoids; canister purge solenoid; feedback carburetor or fuel injector solenoids; throttle kicker solenoid, DC motor ISC, or throttle

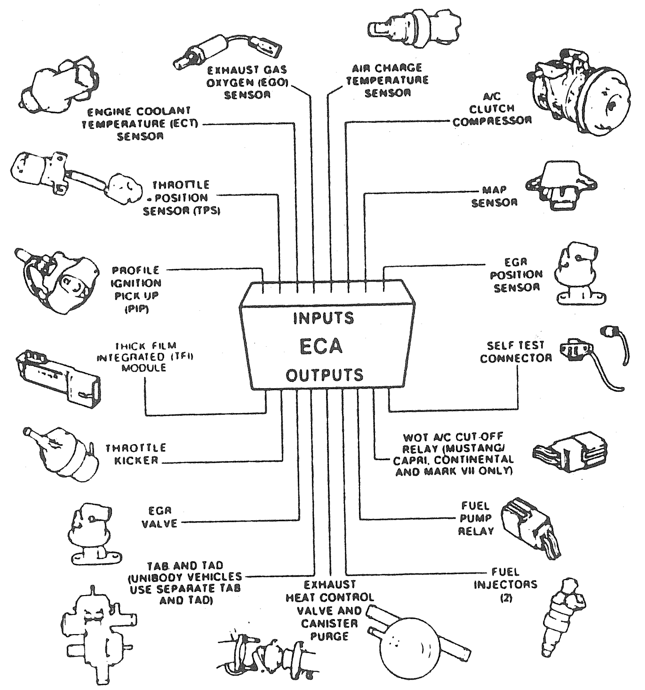


FIGURE 18–61
EEC-IV system operation. (Courtesy of Ford Motor Co.)

air bypass solenoid; ignition module; turbocharger boost solenoid; wide-open throttle A/C shutoff relay; A/C and cooling fan controller module; torque converter clutch solenoid; inlet air system solenoid; variable voltage choke; temperature-compensated accelerator pump system; and shift indicator light.

Note: Not all of these actuators are found on all EEC-IV systems. The actual number used depends on the engine application.

ECA Operating Strategies

As in the case of the EEC-III units, the EEC-IV's ECA operates in three strategies: base engine, modulator, and limited operational. The base and modulator strategies are identical in both ECAs with one exception. In the EEC-IV system, there are also provisions in the base engine strategy for an underspeed mode. When the engine starts to stumble during operation, this mode helps it to recover to prevent stalling.

The limited operational strategy is also changed from that found in an ECA for the EEC-III system. For instance, when the ECA can no longer function under normal strategy, it enters an alternate one. Also, if the central processing unit should fail, the ECA controls the output actuators in a fixed mode, such as no EGR, fixed base timing, and no canister purge.

Adaptive Strategy

In 1985, *adaptive strategy* was added to the EEC-IV's ECA. This feature continually adjusts the calibration values to correct for wear and aging of given components. The adaptive strategy then retains the adjusted values in the keep-alive memory, so they are not lost or canceled when the engine is shut off.

With adaptive strategy, a short learning period will occur on new vehicles, when the battery has been disconnected during normal service, and when an EEC component is replaced or disconnected. In the case of replacement, the memory may need to be cleared to eliminate the adjustment values that were made for the aged or damaged component. It is very possible for engine operation to actually deteriorate after replacement since the ECA will still continue to operate the new part on the adjustment values for the old component until after the learning period. The adjustment or learning period lasts for about five miles of driving.

18-5 FORD MCU SYSTEM

Ford Motor Company introduced the *microprocessor control unit (MCU) system* in 1980 for use on the California 2.3-liter engine. Since then, the MCU system has been used on a number of different automobiles and light trucks (Fig. 18-62). Like the EEC systems, the function of the MCU system is to provide a vehicle with maximum fuel economy, good driveability, and acceptable exhaust emission levels. Moreover, the design of the MCU system is basically the same for all vehicles, whether car or truck. However, minor variations exist on different engine applications.

System Inputs

Exhaust Gas Oxygen Sensor. The exhaust gas oxygen (EGO) sensor found on the MCU system is the same type used on the EEC-II, III, and IV systems (Fig. 18-63). The EGO sensor signal to the microcomputer is used to determine the exact air/fuel ratio on which the engine is operating.

To perform this function, the EGO is located in the exhaust manifold, so it is exposed to the stream of exhaust gases. In this location, the sensor gener-

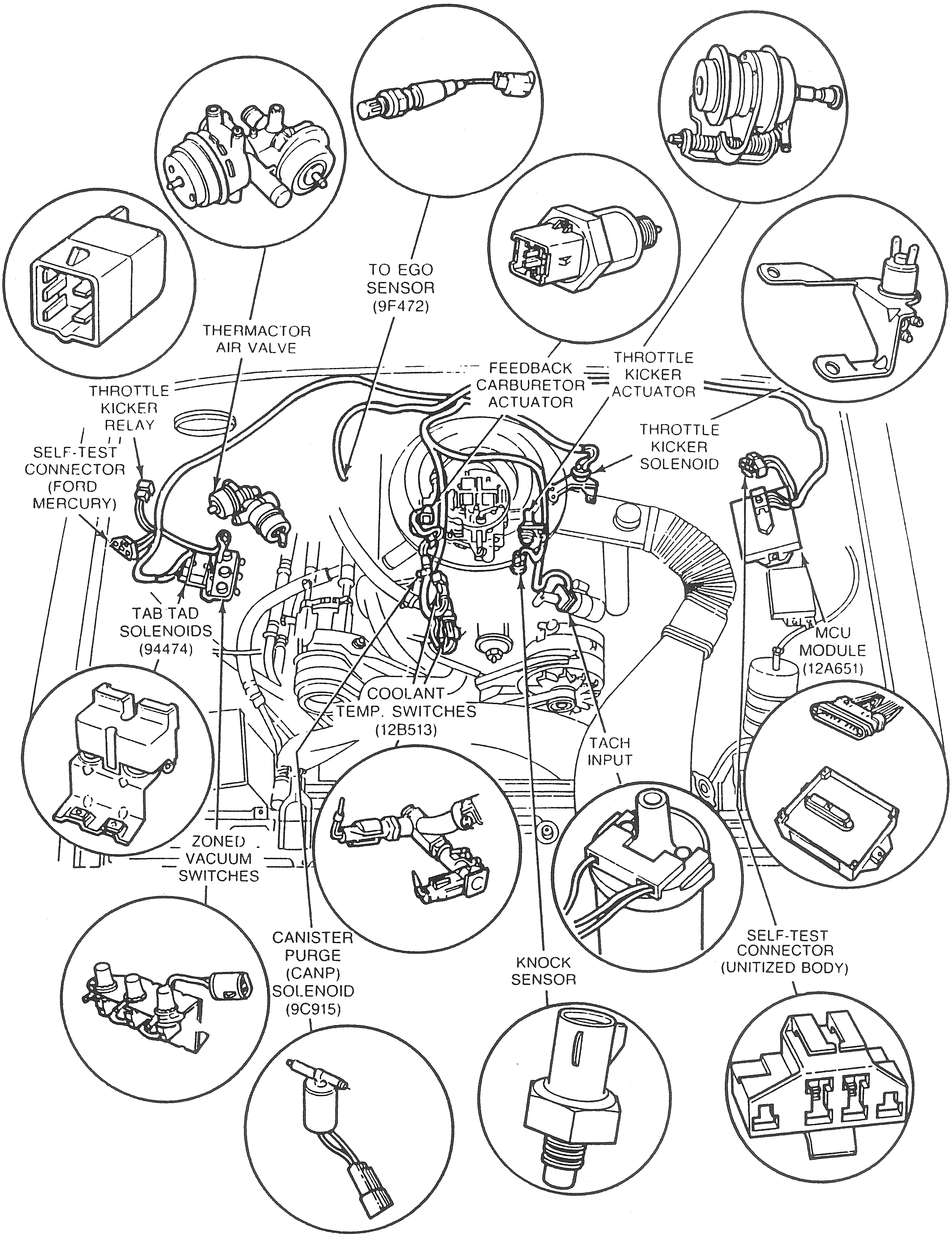


FIGURE 18–62
Typical MCU system. (Courtesy of Ford Motor Co.)

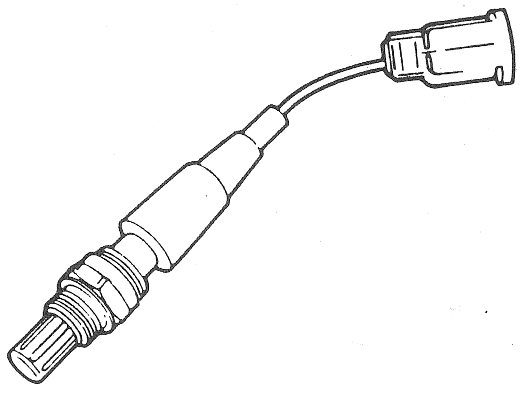


FIGURE 18-63
EGO sensor. (Courtesy of Ford Motor Co.)

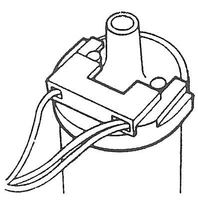


FIGURE 18-64
TACH input signal. (Courtesy of Ford Motor Co.)

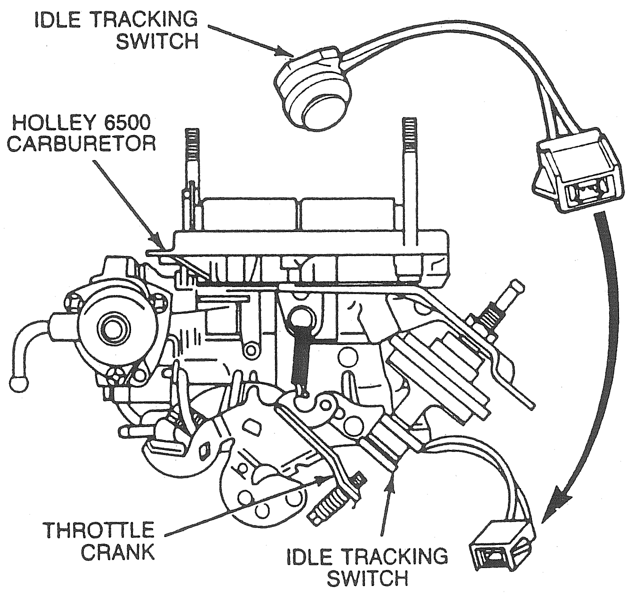


FIGURE 18-65
Idle tracking switch. (Courtesy of Ford Motor Co.)

ates a voltage signal in proportion to the amount of oxygen remaining in the exhaust gas.

When the MCU system is operating in the open loop mode, the EGO sensor voltage may average between 0 volts and 1.0 volt. However, with the EGO sensor at operating temperature and the system in closed loop, the electrical signal from the EGO sensor varies on either side of 0.5 volt. For example, below 0.5 volt, the signal indicates that an excessive amount of oxygen exists in the exhaust gas because the carburetor is supplying a lean air/fuel ratio. On the other hand, a signal above 0.5 volt indicates an insufficient oxygen content, signifying a rich mixture.

TACH Input Signal. All vehicles equipped with MCU use the *TACH input signal* to control any air/fuel ratio changes (Fig. 18-64). When the microcomputer directs an output signal to change the carburetor's air/fuel ratio, a smooth transition to the revised ratio must occur. In other words, any overcorrection or sudden change must be avoided.

The microcomputer can only provide a smooth change in the air/fuel ratio if it has an rpm signal. This signal comes as a ground pulse, known as the TACH input signal, from the ignition coil's primary circuit. The frequency of this input signal is proportional to the engine speed and governs the damping of the microcomputer's air/fuel ratio output signal.

Idle Tracking Switch. The *idle tracking switch* is a mechanically operated electrical switch mounted on a bracket near the throttle crank lever of the Holley 6500 carburetor (Fig. 18-65). The function of the switch is to signal the microcomputer of a closed-throttle condition like an uninterrupted idle or prolonged deceleration.

The idle tracking switch is normally closed. It opens at closed throttle when the throttle linkage rotates to the closed position and the crank lever screw makes contact and opens the switch.

When the switch is open, its circuit to the microcomputer is open. The microcomputer then enters a closed throttle mode, which means it changes the carburetion and Thermactor air operation to meet the engine's requirements during this period.

Wide-Open Throttle Vacuum Switch. The *wide-open throttle vacuum switch* is a normally closed electrical switch that is actuated by intake manifold vacuum (Fig. 18-66). The switch is used to signal the microcomputer of a wide-open throttle condition and for cold start fuel control. This latter function is

accomplished by routing its vacuum signal through the temperature sensing vacuum valve in the air cleaner.

With the engine warmed up and at idle, the temperature sensing vacuum valve is open to permit engine manifold vacuum to the wide-open throttle vacuum switch. This vacuum keeps the switch open.

As the throttle opens and manifold vacuum falls off below the set point of the wide-open throttle switch, it closes. With the switch closed, a signal is sent to the microcomputer to adjust the engine's wide-open throttle operating conditions.

Knock Sensor. A knock sensor is found on some MCU system applications with V-6 and V-8 engines. The sensor primarily functions when the system is in closed loop, so the engine can operate with the best ignition timing possible without detonation.

The sensor is a tuned-crystal pickup, selectively responsive to any spark knock due to detonation (Fig. 18–67). Detonation can result from advanced ignition timing, poor fuel octane, or changes in altitude.

When a spark knock occurs, the knock sensor provides a pulsating signal to the microcomputer. This unit then compensates for overadvanced ignition timing by retarding it. The microcomputer accomplishes this by directing an output signal to the spark retard solenoid.

Engine Coolant Temperature Switches. The MCU system uses some form of coolant temperature switch. This unit senses the engine's coolant temperature and relays an electrical input signal to the microcomputer. The switches used in the various MCU applications perform the same function but differ in design.

Low-Temperature Switches. The 2.3-liter engine uses a *low-temperature switch* that is integral with the three-port ported vacuum switch (PVS) in the EGR control system (Fig. 18–68). This particular switch only senses the low range of coolant temperature and closes at or above 95°F (35°C). With the switch closed, it completes a ground for the low temperature circuit to the microcomputer. As a result, the microcomputer makes the required air/fuel mixture adjustment as the engine temperature moves from cold to normal operation.

The 4.9-liter California engine also has a low-temperature switch that operates by vacuum, but it is not part of the PVS (Fig. 18–69). Instead, the switch is one of a bank of units that are remotely mounted at the rear of the engine compartment.

This low-temperature vacuum switch is uti-

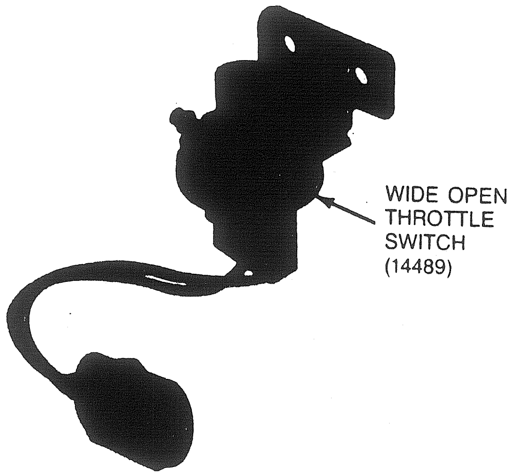


FIGURE 18–66
Wide-open throttle vacuum switch. (Courtesy of Ford Motor Co.)

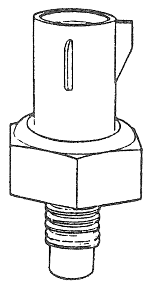


FIGURE 18–67
Knock sensor. (Courtesy of Ford Motor Co.)

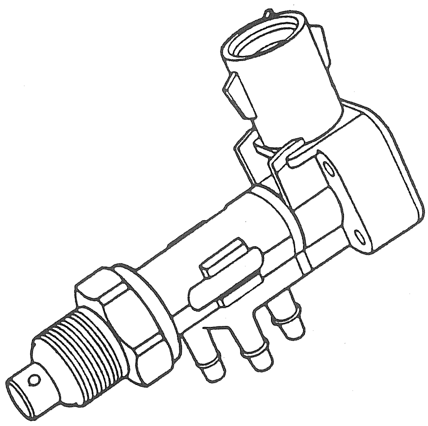


FIGURE 18–68
Low-temperature switch for a 2.3-liter engine. (Courtesy of Ford Motor Co.)

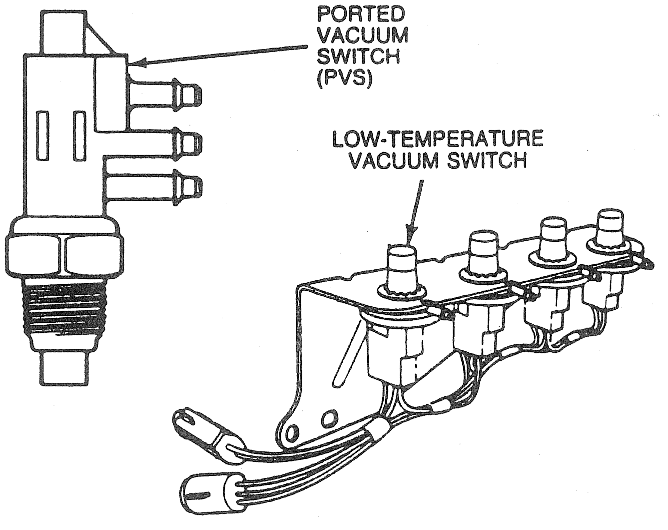


FIGURE 18–69
Low-temperature switch for a 4.9-liter engine. (Courtesy of Ford Motor Co.)

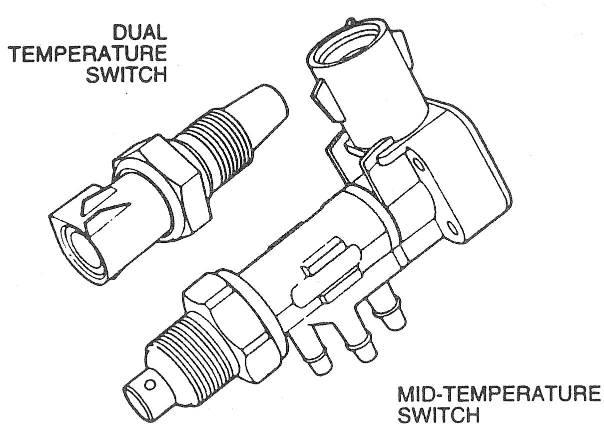


FIGURE 18–70
Mid- and dual-temperature switches. (Courtesy of Ford Motor Co.)

lized in conjunction with a separate PVS. For instance, at or above 95°F (35°C), the PVS cuts off vacuum to the low-temperature switch. With zero vacuum applied, the low-temperature switch closes and grounds the circuit to the microcomputer. The microcomputer then changes the air/fuel ratio for engine operation at normal operating temperature.

Mid- and Dual-Temperature Switches. V-6 and V-8 engines equipped with the MCU system use two temperature switches, the mid- and dual-temperature switches (Fig. 18–70). Both of these units are electrical switches that direct input signals to the microcomputer. These signals cover a wide range of engine coolant temperatures.

The *mid-temperature switch* is integral with a PVS. This switch closes at or above 128°F (53°C) and completes a ground circuit to the microcomputer. The opening and closing of the switch and the resulting completion or breaking of the ground circuit is its input signal.

The *dual-temperature switch* is an electrical switch that senses both low-temperature and overheating conditions. It closes between 55°F (13°C) and 235°F (113°C). Again, the opening and closing of the switch forms the input signal to the microcomputer.

The microcomputer responds to the input signals from the coolant switches and compensates for various engine operating conditions. The microcomputer may then alter as necessary, the air/fuel ratio, engine timing, throttle position, control of Thermactor air, or canister purging.

Vacuum Switch Assembly. Along with low-temperature switch, the 4.9-liter California engine has three other vacuum switches mounted as an assembly at the rear of the engine compartment (Fig. 18–71). These switches open by vacuum and close when it drops below the set point of each switch. The wide-open, crowd, and low-temperature switches connect to the intake manifold vacuum fitting. The closed throttle switch connects to the third-port vacuum on the carburetor.

These switches provide input signals for use during the system's closed loop mode of operation. The microcomputer uses the signals to determine air/fuel ratio and precise control of Thermactor air.

Zoned Vacuum Switch Assembly. V-6 and V-8 engines use three *zoned vacuum switches* to sense throttle position under various engine load conditions (Fig. 18–72). All of these switches provide input signals to the microcomputer relative to throttle position. These signals are in the form of breaking or completing a particular microcomputer ground circuit. For example, the *high and low vacuum switches* are electrically connected in parallel. In operation, their circuits ground under a high-vacuum condition (closed throttle) or low-vacuum condition (wide-open throttle) as the switches close.

On the other hand, the *mid-vacuum switch* closes its circuit under medium-to-high manifold vacuum such as during a cruise (part-throttle) condition. However, the switch opens when manifold

vacuum falls below a switch set point under wide-open throttle or crowd conditions.

System Outputs

Canister Purge Solenoid. The canister purge (CANP) solenoid consists of an electrically operated valve that controls the flow of fuel vapors from the carbon canister to the intake manifold (Fig. 18–73). This solenoid is similar in design and operation to the one used on the EEC systems.

Spark Retard Solenoid. The microprocessor control unit (MCU) system used for the 4.9-liter engine makes use of a *spark retard solenoid* (Fig. 18–74). The microcomputer directs an output signal to energize the solenoid during wide-open throttle acceleration if a spark knock occurs. The solenoid, in turn, bleeds vacuum off the distributor vacuum advance diaphragm to retard the ignition timing.

Thermactor Air Control Solenoids. All MCU applications also have Thermactor air control solenoids (Fig. 18–75). These solenoids are similar in design and operation to those used on EEC systems. They are electrically controlled by output signals from the microcomputer and are utilized to divert air injection to either the upstream or downstream locations or to the atmosphere.

Throttle Kicker Solenoid and Actuator. Other output devices on all MCU applications are the throttle kicker solenoid (TKS) and actuator (Fig. 18–76). These are used to increase engine idle as necessary by opening the throttle. Both the TKS and actuator are similar in design and operation as those found on certain EEC systems.

Vacuum Regulator Solenoid. On MCU systems, there are three different devices that can be used to control the air/fuel ratio. For example, the 2.3-liter MCU engine incorporates a *vacuum regulator solenoid (VRS).* The VRS (Fig. 18–77) contains a vacuum regulator that passes a feedback vacuum to the air/fuel mixture control diaphragm located on the Holley 6500 carburetor. The calibrated feedback vacuum ranges from 0 inches Hg (0 kPa) for full enrichment to 5 inches Hg (17 kPa) for full lean operation.

Fuel Control Solenoid. On the 4.9-liter and late 2.3-liter applications, a *fuel control solenoid (FCS)* al-

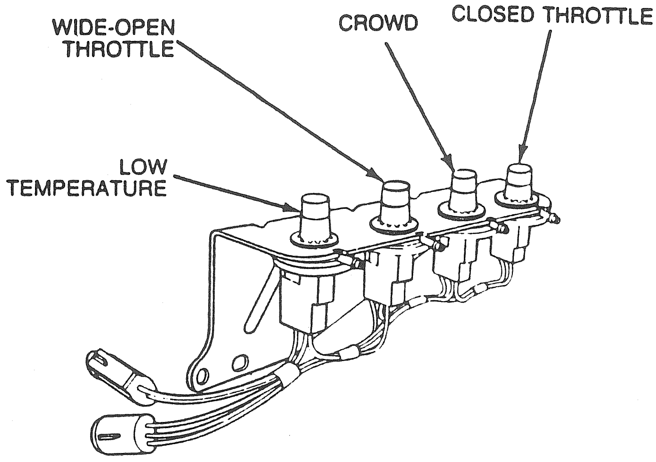


FIGURE 18–71
Vacuum switch assembly. (Courtesy of Ford Motor Co.)

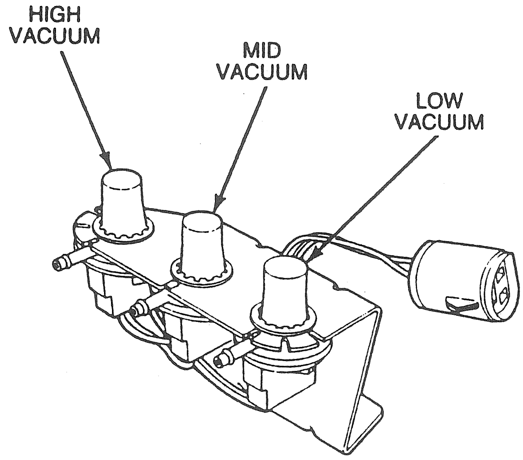


FIGURE 18–72
Zoned vacuum switch. (Courtesy of Ford Motor Co.)

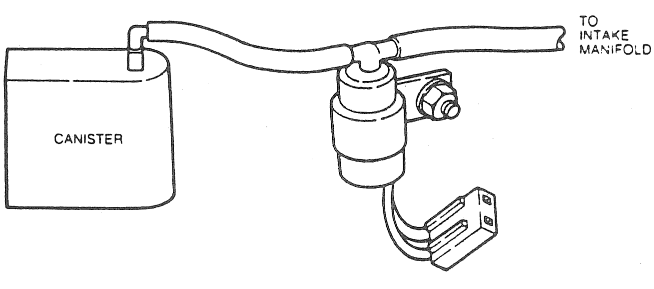


FIGURE 18–73
Canister purge solenoid. (Courtesy of Ford Motor Co.)

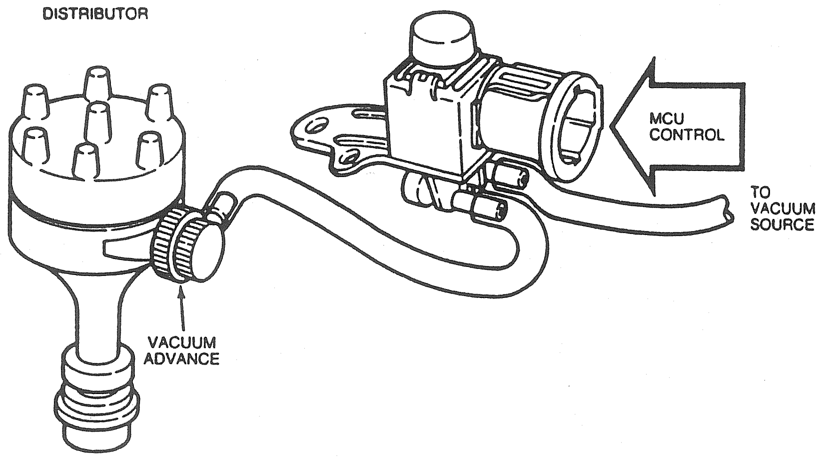


FIGURE 18–74
Spark retard solenoid. (Courtesy of Ford Motor Co.)

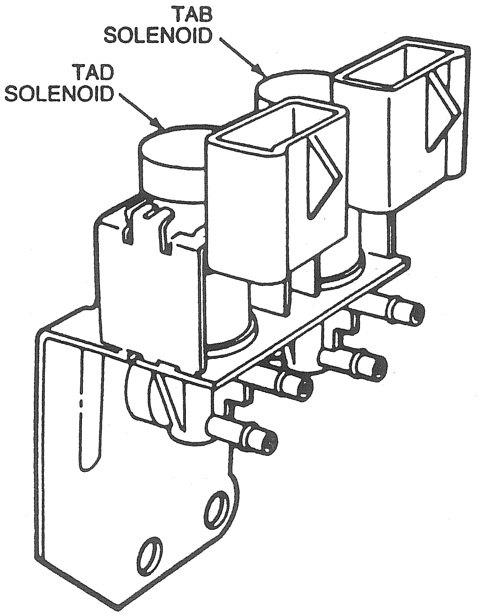


FIGURE 18–75
TAB and TAD solenoids for microprocessor control unit. (Courtesy of Ford Motor Co.)

ters the air/fuel ratio. The solenoid itself mounts directly on the YFA-IV carburetor (Fig. 18–78).

The FCS is energized by a pulsating output signal from the microcomputer that grounds the solenoid. This permits a voltage pulse of ten cycles per second, with an average value of nearly 10 volts, to pass through the solenoid. The solenoid, in turn, leans or enriches the air/fuel ratio at the carburetor.

Feedback Carburetor Actuator. The 3.9-liter V-6, and 4.2-liter, 5.0-liter, and 5.8-liter V-8 engines use a *feedback carburetor actuator (FBCA)* to regulate the air/fuel ratio. The actuator mounts directly on the model 7200 VV 20-V carburetor, and it is the same one used on the EEC-III system.

The microcomputer used with this actuator has four output signal circuits that energize the four windings in the FBCA. Energizing the windings extend or retract the actuator's stepper shaft in one of its 120 positions. The stepper shaft operates a metering pintle in the air bleed jet inside the feedback carburetor.

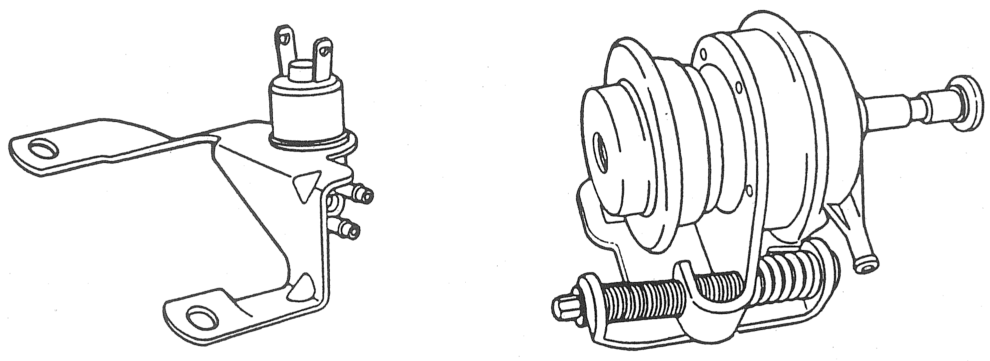


FIGURE 18–76
Throttle kicker solenoid and actuator. (Courtesy of Ford Motor Co.)

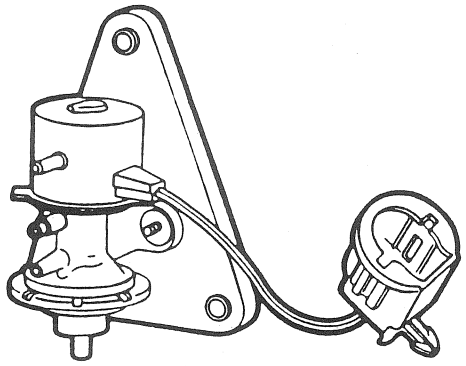


FIGURE 18-77
Vacuum regulator solenoid. (Courtesy of Ford Motor Co.)

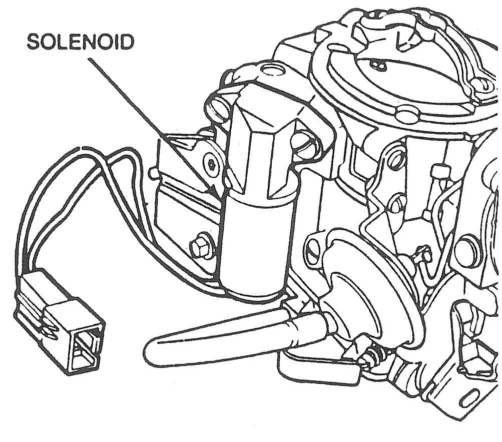


FIGURE 18-78
Fuel control solenoid. (Courtesy of Ford Motor Co.)

Microprocessor Control Unit

The MCU system is named after its microcomputer, that is, the *microprocessor control unit* (Fig. 18-79). The MCU operates in a similar manner as the ECA found on the EEC systems but is mounted in the engine compartment instead of inside the vehicle. Moreover, the MCU does not perform as many functions as the ECA.

The MCU operates in three fuel control modes. These permit it to provide the vehicle with reduced emission levels, good fuel economy, and improved driveability. These three fuel control modes are initialization, closed loop, and open loop.

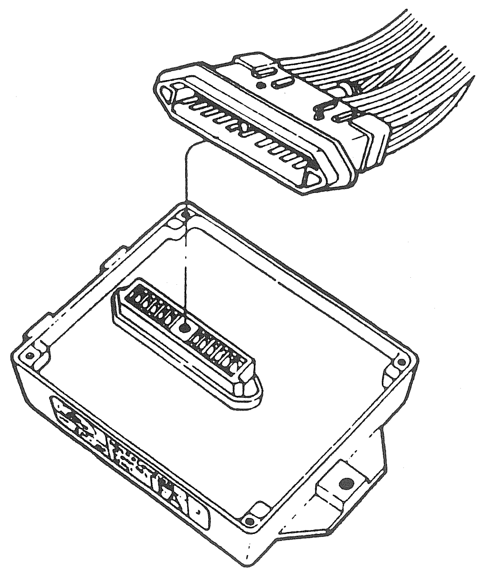


FIGURE 18-79
Microprocessor control unit. (Courtesy of Ford Motor Co.)

MCU Initialization Mode

The *MCU initialization mode* of operation occurs when the system activates after turning on the ignition switch and for a brief moment after the engine starts. During this mode, the MCU program maintains a rich air/fuel ratio for ease of engine starting. The Thermactor air subsystem does not have time to operate because the initialization mode is so short. However, this system does come into operation as soon as the MCU switches to either the closed or open loop mode.

MCU Closed Loop Mode. During the *MCU closed loop mode* of operation, the system provides as closely as possible the ideal air/fuel ratio of 14.7:1. The MCU system enters the closed loop mode when the engine is operating at normal temperature and when the engine is running under light load, part-throttle conditions.

To maintain the ideal ratio, the MCU monitors the exhaust gas by means of the EGO sensor signal to determine the actual air/fuel mixture being delivered by the carburetor. As necessary, the MCU signals the carburetor actuator to either lean out or enrich the mixture. Also during this mode, Thermactor air is injected downstream to the catalytic converter.

MCU Open Loop Mode The *MCU open loop mode* occurs during four phases of engine operation: (1) when the engine is operating at less than normal temperature, (2) during full throttle acceleration, (3) during deceleration, and (4) during idle.

When the engine is below its normal operating temperature, the system has to operate in open loop to provide an enriched mixture to promote vehicle driveability. Furthermore, until the EGO sensor

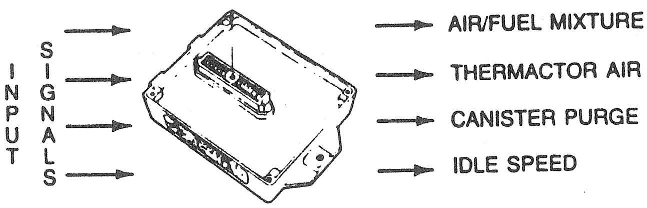


FIGURE 18-80
MCU operation. (Courtesy of Ford Motor Co.)

reaches its operating temperature, its signals to the MCU are not reliable, so they cannot be used to regulate the air/fuel ratio.

As the throttle is opened from the part to the wide-open position during acceleration, the air/fuel ratio must enrich. The MCU signals the carburetor actuator to provide a fixed ratio just rich enough to assure good engine response and performance. In addition, the MCU momentarily diverts Thermactor air from the catalytic converter to the upstream location at the exhaust manifolds.

Whenever the engine operates under a prolonged deceleration or uninterrupted idle, the MCU functions in open loop as the throttle closes. The MCU, responding to sensor input at this time, provides either a rich or lean air/fuel mixture depending on engine requirements and emission levels.

MCU System Operation

During engine operation, the MCU constantly monitors the input signals from the sensors (Fig. 18-80). The input signals to the MCU, depending on engine application, include EGO (during closed loop operating mode only), vacuum switches, idle tracking, TACH, knock sensor, and engine coolant temperature.

After receiving the input signals, the MCU analyzes engine performance against data programmed into its memory. After computing the correct air/fuel ratio, canister purge rate, engine idle, Thermactor air control, and spark retard, the MCU directs output signals as needed to the canister purge solenoid, spark retard solenoid, Thermactor air solenoids, feedback carburetor control, and throttle kicker solenoid.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. In operation, the MCU controls which engine or emission system functions [18-5]?
2. Why couldn't the EEC-I system operate in closed loop [18-1]?
3. Why does the EEC-IV system require so many input sensors [18-4]?
4. Describe the input and output sensors for the EEC-II system [18-2].
5. Where is the location of the TP sensor used on an EEC-III system with central fuel injection [18-3]?

REVIEW

1. During engine start-up, the MCU operates in the [18-5]
   a. open loop mode.
   b. closed loop mode.
   c. initialization mode.
   d. both a and b.
2. On the EEC-I system, what determines reference timing [18-1]?
   a. distributor Hall-effect switch
   b. distributor pickup coil
   c. CP sensor and pulse ring
   d. camshaft sensor
3. If a detonation occurs in some MCU applications, the microcomputer directs an output signal to the [18-5]
   a. distributor actuator.
   b. distributor spark retard solenoid.
   c. distributor pickup coil.
   d. ignition module.
4. Which EEC-I sensor provides an input signal indicating driver demand on the engine [18-1]?

a. CP
b. TAP
c. CTS
d. TAB

5. The rpm input signal to the MCU comes from the [18-5]
a. CP sensor.
b. PIP sensor.
c. TACH coil terminal.
d. either a or b.

6. The EEC-I's EGR solenoids control what type of signal to the EGR diaphragm [18-1]?
a. air pressure
b. vacuum
c. electrical
d. electronic

7. The EGO sensor produces higher voltage with what type of air/fuel mixture [18-5]?
a. rich
b. lean
c. 14.7:1
d. 18:1

8. In operation, the ECA of the EEC-I system controls how many actuators [18-1]?
a. one
b. two
c. three
d. four

9. What component is used to regulate the idle speed on the EEC-IV system [18-4]?
a. ISC
b. vacuum kicker
c. throttle air bypass valve
d. all of these

10. How much reference voltage is used in the EEC-II system [18-2]?
a. 5 volts
b. 9 volts
c. 12 volts
d. 0 volts

11. A low-pressure injector is used in which EEC-IV system [18-4]?
a. CFI
b. multipoint
c. both a and b
d. neither a nor b

12. Which EEC-II input sensor is the voltage-generating type [18-2]?
a. CP
b. EGO
c. both a and b
d. neither a nor b

13. Which EEC-IV sensor produces a frequency-type input signal [18-4]?
a. distributor
b. EGO
c. MAP and BAP
d. ECT

14. What output actuator regulates the idle speed in the EEC-II system [18-2]?
a. ISC motor
b. throttle kicker
c. throttle solenoid
d. throttle air bypass

15. In the EEC-IV system, which TP sensor incorporates a cam-operated plunger [18-4]?
a. linear
b. rotary
c. both a and b
d. neither a nor b

16. In the EEC-II system, the ECA signals which actuator to alter the air/fuel ratio [18-2]?
a. AIS motor
b. injector
c. stepper motor
d. none of these

17. If the EEC-III's ECA has a malfunction, the engine operates in which strategy [18-3]?
a. base
b. LOS
c. modulator
d. both b and c

18. The EEC-III system must have what additional sensor when CFI is used [18-3]?
a. TP
b. EGO
c. ECT
d. ACT

19. During normal operation, the EEC-III system operates in which strategy [18-3]?
a. base engine
b. modular
c. LOS
d. none of these

20. The fuel injector energized or open period is called [18-3]
a. duty cycle.
b. pulse width.
c. both a and b
d. neither a nor b

Chapter 19

TESTING A TYPICAL FORD EEC-IV SYSTEM

OBJECTIVES

After reading and studying this chapter, you will be able to

- describe the purpose and types of diagnostic routines.
- identify and know the purpose of the various pieces of equipment used to self-test the EEC-IV system.
- explain the function of and be able to obtain service codes using an analog voltmeter and a STAR tester.
- define the various types of service codes.
- describe the function and procedure for performing an EEC-IV quick test.
- explain the purpose and procedure for performing an EEC-IV pinpoint test.

DIAGNOSITC ROUTINE INDEX

ROUTINE	TITLE	PAGE
201	Cranks Normally But Won't Start	2-3
202	Starts Normally But Won't Run (Stalls)	2-4
203	Cranks Normally But Slow to Start	2-5
204	Rough Idle	2-6
205	Misses Under Load	2-7
206	Stalls on Deceleration or Quick Stop	2-7
207	Hesitates or Stalls on Acceleration	2-8
208	Backfire (Induction or Exhaust)	2-8
209	Lack of Power	2-9
210	Surges at Steady Speed	2-9
211	Engine Diesels (or Idles too Fast)	2-10
212	Engine Noise	2-10
213	Poor Fuel Economy	2-11
214	High Oil Consumption	2-11
215	Spark Knock/Pinging	2-12
216	Engine Vibrates at Normal Speeds	2-12
217	Engine Runs Cold	2-12
218	Engine Runs Hot	2-13
219	Exhaust Smoke	2-13
220	Gas Smell	2-14

FIGURE 19–1
Diagnostic routine index. (Courtesy of Ford Motor Co.)

As pointed out in the last chapter, Ford has produced five electronic engine control systems to date. Although there are similarities among these systems, they all require different testing procedures. Due to space limitations, this chapter presents the diagnostic procedures for only the EEC-IV system to familiarize you with the process. Keep in mind, however, that there are even differences in procedure within the EEC-IV system due to the various engines on which it is installed. *Always follow the recommended procedures as set forth in Volume H of the Car Shop Manual for the year of the vehicle you are testing. Otherwise, you can damage or replace a serviceable component.*

19-1 DIAGNOSTIC ROUTINES

Before examining the diagnostic routines, there are some very important, basic facts that must be considered before testing any computerized engine control system. First, the vehicle has to have a sound engine for the microcomputer to control. That is, the ignition system and internal engine components must be in good functioning order. In addition, the carburetor or fuel injection system has to be serviceable.

Second, a malfunction must first be treated as if the engine did not have a computerized control system. In other words, visual inspections and commonly performed testing procedures used to solve any engine operating problem are still valid and are the smartest way to deal with a problem. Remember, there is absolutely no sense in looking into the computerized system and spending your valuable time and effort when the cause of the problem probably exists somewhere else.

Even if the computerized system has self-diagnosis capabilities, it is not programmed to detect problems *other than within itself.* Therefore, it will not inform you that a spark plug is misfiring, the plugs are in the wrong heat range, the rotor or cap is cracked, an intake or exhaust valve is burned or not seating, or a vacuum hose is disconnected.

In other words, there are many problems that are not within the microcomputer system that can create driveability complaints. The causes of these are found using the many basic checks, inspections, and performance tests that you should already be familiar with.

With these facts in mind, let's begin Ford's approach to diagnosing its EEC-IV system. First of all, you never perform EEC-IV diagnostics until instructed to do so by the *diagnostic routines* found in Volume H of the shop manual for the year of the car with the malfunction. Figure 19-1 illustrates an index to typical diagnostic routines. Each routine on the index is listed by a malfunction title and provided with a number, such as 201, for the problem "Cranks Normally But Won't Start." Also, the index provides the page number on which a particular routine can be found.

A typical diagnostic routine (Fig. 19-2) lists the components or systems that can cause a particular problem. These are listed in order of their probability of failure, ease of routine accomplishment, and component or system accessibility. Notice in the example that EEC/MCU component diagnostics is next to the last as a probable cause of the no-engine-start condition.

Each routine can be used as a check list for reference in locating the cause of unusual or infrequent malfunctions. When using a given routine, it is not usually necessary that any given order of item check off be followed, with the exception of EEC/MCU components. These should always be nearly the last items to check. However, it not only makes good sense but is a must that you check each item on the routine before beginning a more involved diagnosis. By doing so, the cause of a particular problem may be found quickly without the need of testing the microcomputer system.

In the reference column of each routine you will find section and group numbers. A group number refers to one found in the Powertrain, Body, or Chassis Shop Manual for a given year of vehicle. On the other hand, a section number refers to a section within the same Emission Diagnosis/Engine Electronic Shop Manual in which the routines are found. For example, component diagnoses for the EEC/MCU system are found in Section 16-28 of the manual used in the example.

201	CRANKS NORMALLY BUT WON'T START	
System	**Component**	**Reference**
Ignition	Electrical Connections Secondary Ignition Wires Ignition Coil Ignition Module Rotor Alignment Distributor Cap, Adapter, Rotor & Stator Spark Plugs Fouled Ignition Switch	Section 15 Group 23
External Carburetor/Fuel Charging Assy./Throttle Body	Electrical and Vacuum Connections Choke Plate and Linkage Cold Enrichment Rod and Linkage (7200) Venturi Valve (7200) Throttle Linkages	Visual Section 4 and Group 24
EGR	Valve	Section 6
Internal Carburetor	Float/Inlet Needle and Seat Idle Air Bleeds and Fuel Passages	Section 4 and Group 24
Fuel Delivery	Filter Pump Water/Dirt/Rust Contamination in Fuel Lines Tank (Fuel Supply) Dual Tanks (Selector Switch) Sender Filter Inertia Switch	Visual Section 11 (for mechanical pumps) Sections 16-28 (for electric pumps) and Group 24
EEC/MCU	Component Diagnostics	Sections 16-28
Basic Engine	Camshaft Timing Compression	Group 21

NOTE: Extended cranking, because of a "No Start" condition, can load the exhaust system with raw fuel, which can ruin the catalytic converter after the engine starts. To prevent this, disconnect the thermactor air supply (and, if EFI/CFI, the injectors), and run engine until surplus fuel is used up before reconnecting.

FIGURE 19-2
Typical diagnostic routine. (Courtesy of Ford Motor Co.)

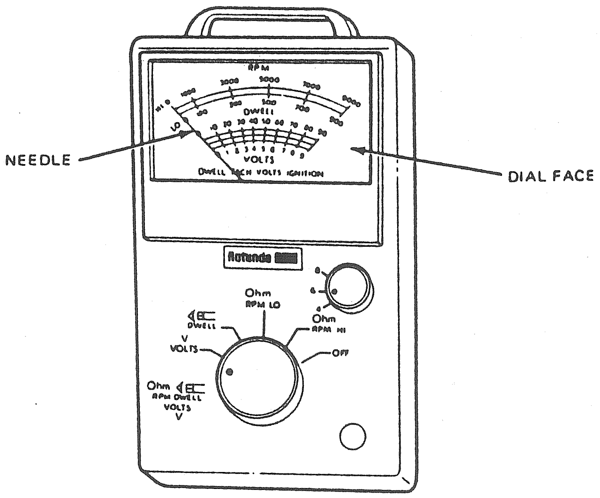


FIGURE 19-3
Analog voltmeter. (Courtesy of Ford Motor Co.)

19-2 SERVICE CODES

In order to perform advanced diagnostics on the EEC-IV system, you must be familiar with service codes and how to interrupt them on an analog voltmeter or STAR tester. *Service codes* are an electronic method for revealing one or more problems that may exist in the computerized engine control system. All service codes are two-digit numerals, but the ECA generates them only one digit at a time. Moreover, each digit is actually produced as a number of timed electrical pulses—two pulses for numeral 2, three pulses for numeral 3, and so forth.

Reading Service Codes on an Analog Voltmeter

There are two ways that you can pull service codes out of the ECA, through the use of either an analog voltmeter (Fig. 19-3) or a STAR tester. The analog voltmeter reveals the service codes as a number of sweeps of the meter needle back and forth across the face of the scale (Fig. 19-4). To obtain the correct service code, simply count the number of needle sweeps.

You may find that the only difficult part in using an analog voltmeter for this purpose is knowing the point at which one digit or entire code ends and another begins. However, the key to sorting out the data is keeping the pauses between the pulses straight in your head. The format for pulse length and pauses during a system self-test is as follows:

- Each digit pulse sweep has a duration of one second—one-half second up scale and one-half second down scale.

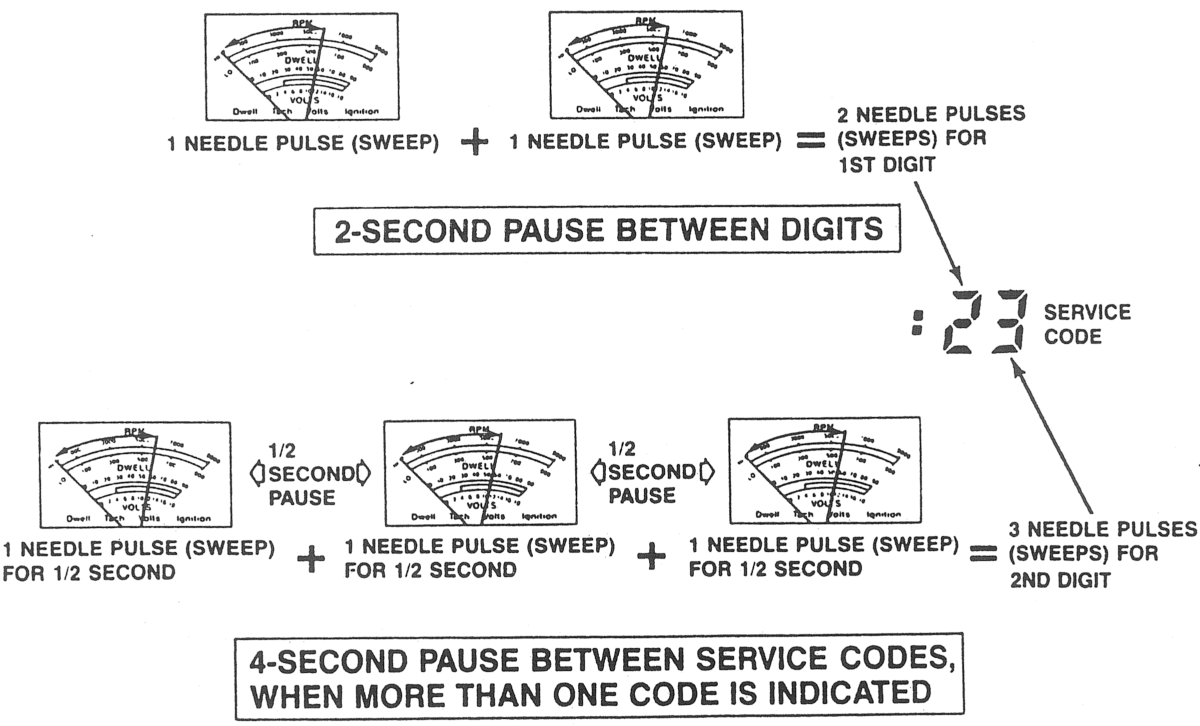


FIGURE 19-4
Reading service codes on an analog voltmeter. (Courtesy of Ford Motor Co.)

- Each digit is separated by a two-second pause.

- Each code is separated by a four-second pause.

- Separator and dynamic response codes are separated from previous and subsequent codes by six-second or longer pauses.

Note: On an analog voltmeter, separator and dynamic response codes (numeral 10 in both cases) are represented by a single pulse or sweep of the needle. No pulses are generated by the digit 0. Separator and dynamic response codes are discussed in the next section.

- All codes are automatically repeated once during a system self-test.

Reading Service Codes on a STAR Tester

The easiest way to read service codes is through the use of a *self-test automatic readout (STAR) tester.* The STAR tester (Fig. 19-5) differs from an analog voltmeter in that the former totals the single-pulse ECA signals and then projects them as a digital code on its display window. As a result, there is less chance for human error with the STAR tester since you do not have to read the needle sweeps, which is somewhat difficult to do.

During a system self-test, the format for pulse length and pauses when using the STAR is as follows (Fig. 19-6):

- Each two-digit digital code has a duration of two seconds.

- Each code is separated by a four-second pause.

- Separator and dynamic response codes are separated from previous and subsequent codes by a six-second or longer pause.

- All codes are automatically repeated once during a system self-test.

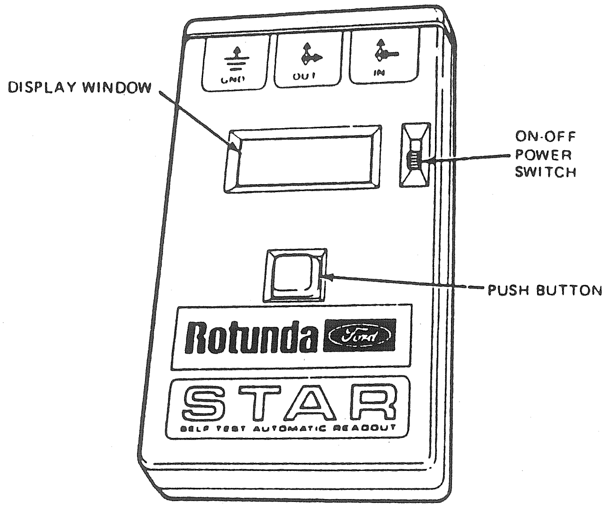


FIGURE 19-5
STAR tester. (Courtesy of Ford Motor Co.)

Connecting the Analog Voltmeter to the Self-Test Connector

In order to read the service codes on either an analog voltmeter or STAR tester, the instrument must be properly connected to the vehicle's *self-test connector,* which is harness-connected to the ECA (Fig. 19-7). As shown in the illustration, the underhood location of this connector varies among the various Ford-built vehicles.

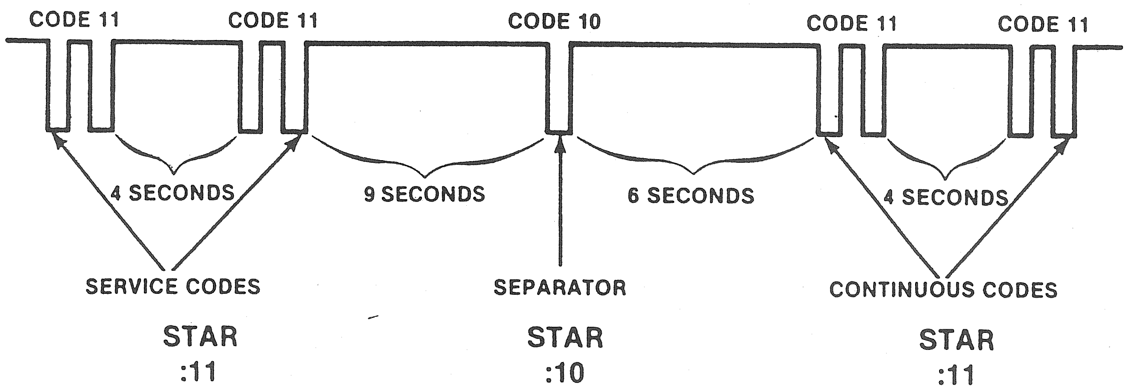


FIGURE 19-6
Reading service codes on a STAR tester. (Courtesy of Ford Motor Co.)

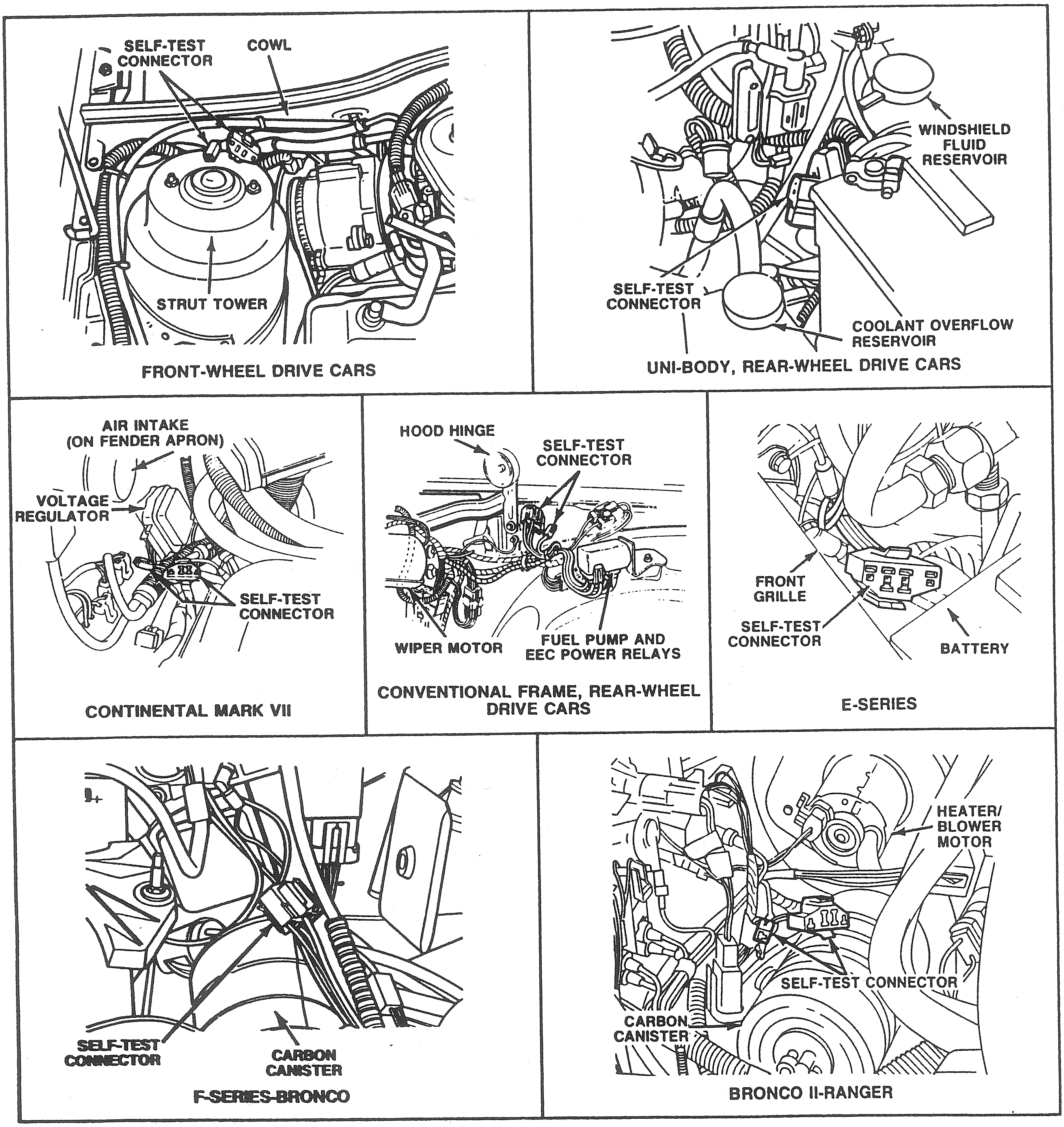


FIGURE 19–7
Typical self-test connector locations (Courtesy of Ford Motor Co.)

However, the hook-up of the analog voltmeter to the self-test connector is the same for all EEC-IV systems except 1983 1.6-liter EFI engine applications. To attach the leads of an analog voltmeter to the self-test connector on all vehicles except the 1983 1.6-liter EFI application, do the following:

1. As necessary, fabricate two jumper wires, four inches to six inches in length, with two male terminal tabs at each end (Fig. 19–8).

2. Make sure the ignition switch is turned off.

3. Set the analog voltmeter on a DC voltage

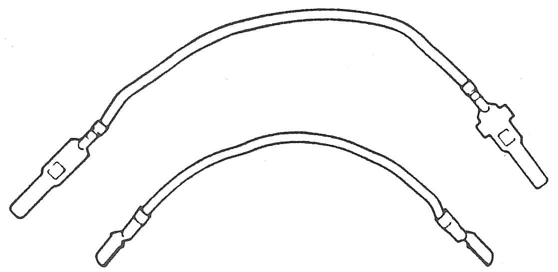


FIGURE 19-8
Jumper wires with male terminal ends. (Courtesy of Ford Motor Co.)

range to read from 0 volts to 15 volts.

4. Insert one end of a jumper wire into the Number 4 pin on the self-test connector (Fig. 19-9).

5. Clamp the negative (−) lead from the analog voltmeter to the other end of the jumper wire.

6. Clamp the positive (+) lead from the analog voltmeter to the positive terminal of the battery (Fig. 19-10).

7. Insert one end of the second jumper wire into the Number 2 pin on the self-test connector. Then insert the other end into the self-test input connector (Fig. 19-11). The last connection to the input connector also activates the ECA self-test sequence when the ignition switch is turned on.

To hook up an analog voltmeter into the EEC-IV system for a 1983 1.6-liter EFI system, do the following:

1. Set the analog voltmeter on a DC voltage range to read from 0 volts to 15 volts. Make sure the ignition switch is off.

2. Insert one end of a jumper wire into the Number 5 pin on the self-test connector and the other end into its Number 2 pin (Fig. 19-12).

3. Clamp the (+) analog voltmeter lead to the positive post of the battery.

4. Connect the negative (−) voltmeter lead to the Number 4 pin on the self-test connector. The ECA self-test sequence will start as soon as the ignition switch is turned on.

Connecting the STAR Tester to the Self-Test Connector

The STAR tester and adapter cable hookup to the self-test and input connectors is the same on all

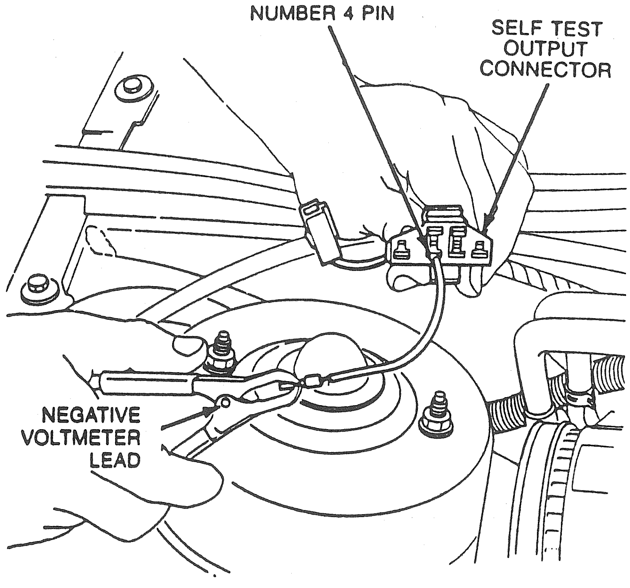


FIGURE 19-9
Installing the jumper wire into the Number 4 self-test connector pin. (Courtesy of Ford Motor Co.)

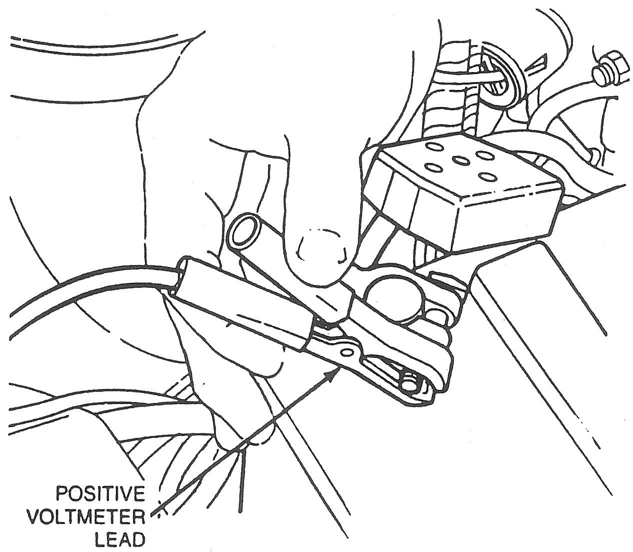


FIGURE 19-10
Clamping the (+) voltmeter lead to the positive battery terminal. (Courtesy of Ford Motor Co.)

Ford-built vehicles with the EEC-IV system. To perform the hookup, follow these steps (Fig. 19-13):

1. Turn the ignition switch to off.

2. Connect the color-coded adapter cable leads to the STAR tester.

3. Plug in the adapter cable's two service connectors to the matching self-test connectors on the vehicle (Fig. 19-14).

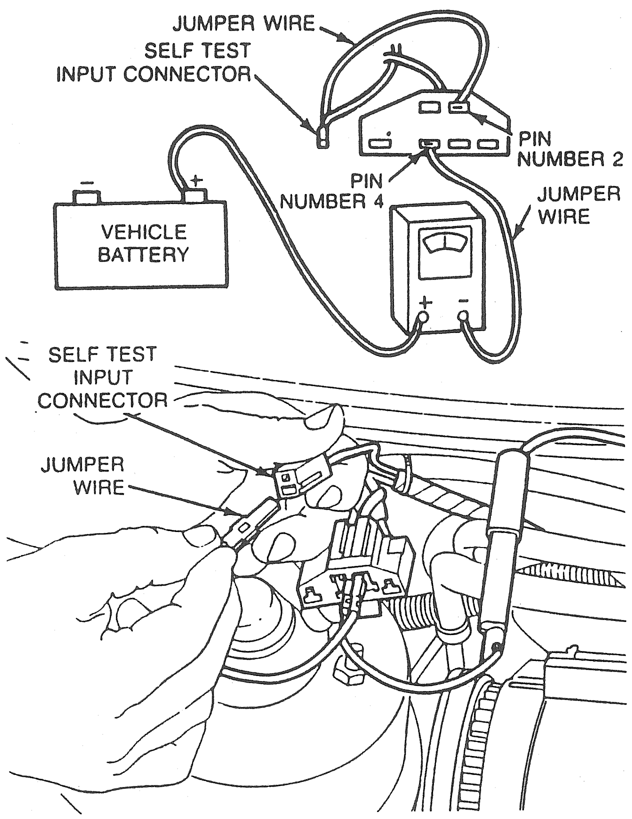


FIGURE 19-11
Installing the jumper wire between the self-test connector Pin 4 and the input connector. (Courtesy of Ford Motor Co.)

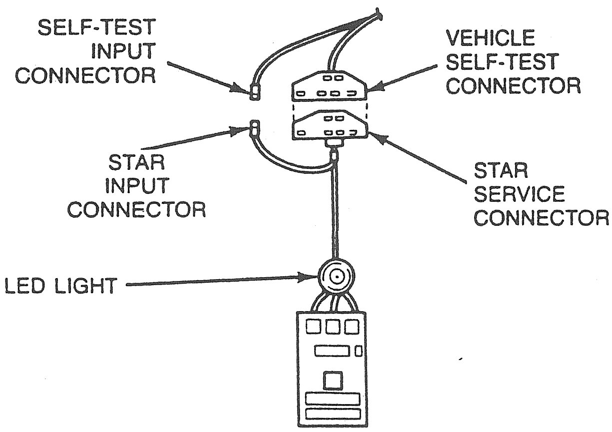


FIGURE 19-13
Hookup for the STAR tester, adapter, and self-test connector. (Courtesy of Ford Motor Co.)

Checking the STAR Tester

To check the STAR tester for serviceability after plugging it into the self-test connector, follow these directions:

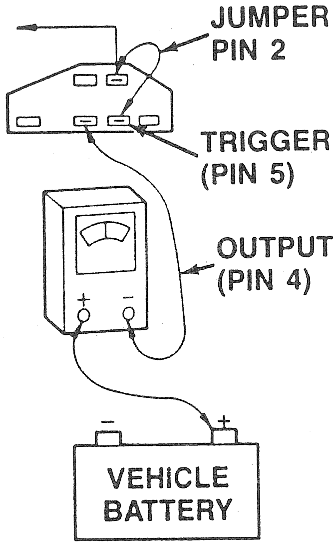


FIGURE 19-12
1983 1.6-liter EFI analog voltmeter hookup. (Courtesy of Ford Motor Co.)

1. Flip the power switch on the right side of the STAR tester to the ON position. The tester will now run a display check, and the numeral 88 will begin to flash in the readout window (Fig. 19-15).

2. A steady 00 will then appear in the window to signify that the STAR tester is ready to start the self-test and receive the service codes.

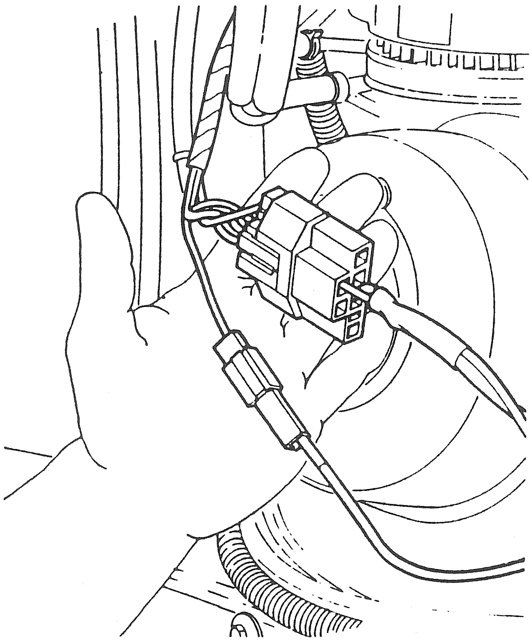
3. If the message LO BAT appears in the left corner of the readout display and stays there, replace the STAR tester's nine-volt battery before proceeding with the self-test procedure.

4. If the LO BAT message appears momentarily when the power switch is turned OFF but then disappears, do not worry about it. This is normal.

5. With the ignition switch still OFF, push the button in the center of the STAR tester, and see if the colon (:) appears in the left side of the readout display. If it does, the tester is serviceable and ready to begin the self-test procedure.

19-3 TYPES OF SERVICE CODES

The ECA of the EEC-IV system produces six types of service codes. However, only four of these have any practical use for service technicians. The six types of codes include separator, memory, fast, engine identification, dynamic response, and on demand.



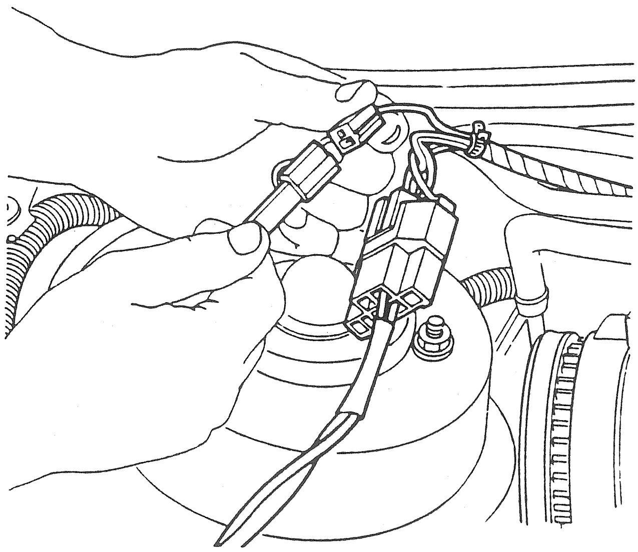


FIGURE 19-14
Plugging in the service and self-test connectors. (Courtesy of Ford Motor Co.)

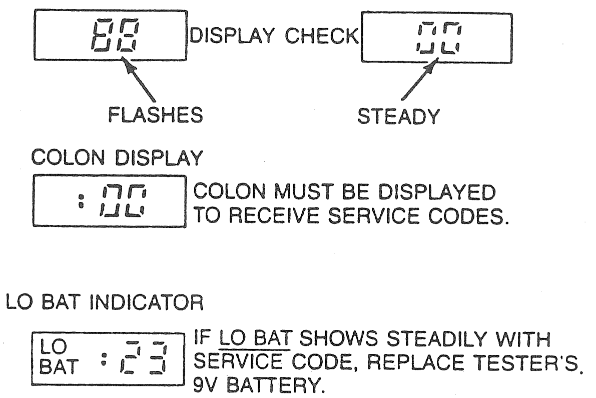


FIGURE 19-15
Checking the STAR tester. (Courtesy of Ford Motor Co.)

Separator Code

The *separator code,* as its name implies, divides two other types of service codes during the key-on, engine-off portion of the EEC-IV self-test. During the self-test, it indicates that the on-demand codes have ceased and memory (continuous) codes are about to begin (see Fig. 19-6). The separator code is displayed on the STAR tester as the numeral 10 and on the analog voltmeter as one needle sweep.

Memory Codes

Memory or *continuous codes* indicate there was a problem somewhere in the EEC-IV recently, such as a short or open circuit, though it is not present at the time of the self-test. This type of problem is referred to as an *intermittent fault.*

All vehicles with the EEC-IV system (with the exception of the 1983 1.6-liter EFI application) have this capability of remembering an intermittent fault. The keep-alive memory within the ECA will store the fault for the next 20 times the ignition key is turned off after the problem occurs. This makes it easier for the technician to diagnose problems that mysteriously disappear when the vehicle is finally brought into the shop.

Fast Codes

During both the key-on, engine-off and engine running self-test sequences, the ECA produces standard service codes at a rate of about 100 times faster than the STAR tester can read them. They can be observed on the analog voltmeter by a slight deflection of the needle or a slight flicker in the LED light on the STAR tester adapter. However, both of these indications can be ignored.

These *fast codes* are read only by special automotive test equipment at the automotive assembly plant. Therefore, they are of no practical use to the service technician in the field.

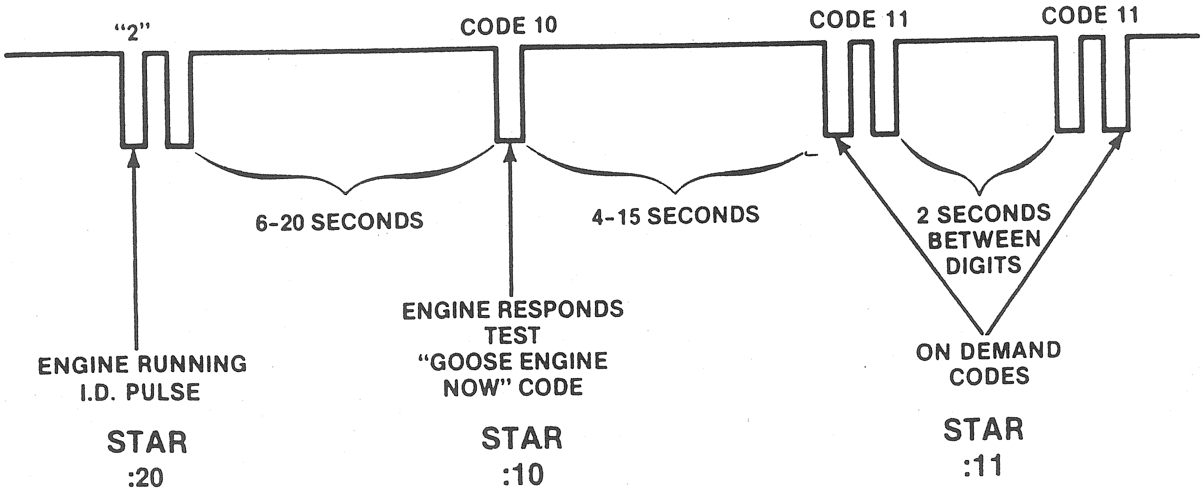


FIGURE 19-16
I.D., dynamic response, and on-demand codes. (Courtesy of Ford Motor Co.)

Engine Identification Codes

Engine identification codes (I.D. pulses) also have no practical application for the service technician (Fig. 19-16). These codes tell automatic equipment at the automotive assembly plant how many cylinders the vehicle's engine has.

When the test button on the STAR tester is

11	System "pass"	55	Electrical charging under voltage
12	Rpm out of spec (extended idle)	56	MAF (VAF) input too high
13	Rpm out of spec (normal idle)	58	Idle tracking switch input too high (engine) running test)
14	PIP was erratic (continue test)	61	ECT input too low
15	ROM test failed	63	TPS input too low
16	Rpm too low (fuel lean test)	64	ACT (VAT) input too low
17	Rpm too low (upstream/lean test)	65	Electrical charging over voltage
18	No tach	66	MAF (VAF) input too low
21	ECT out of range	67	Neutral drive switch — drive or accelerator on (engine off)
22	MAP out of range	68	ITS open or AC on (engine-off test)
23	TPS out of range	72	No MAP change in "goose test"
24	ACT out of range	73	No TPS change in "goose test"
25	Know not sensed in test	76	No MAF (VAF) change in "goose test"
26	MAF (VAF) out of range	77	Operator did not do "goose test"
31	EVP out of limits	81	Thermactor air bypass (TAB) circuit fault
32	EGR not controlling	82	Thermactor air diverter (TAD) circuit fault
33	EVP not closing properly	83	EGR control (EGRC) circuit fault
34	No EGR flow	84	EGR vent (EGRV) circuit fault
35	Rpm too low (EGR test)	85	Canister purge (CANP) circuit fault
36	Fuel always lean (at idle)	86	WOT A/C cut-off circuit fault (all 3.8L and 5.0L Continental)
37	Fuel always rich (at idle)	87	Fuel pump circuit fault
41	System always lean	88	Throttle kicker circuit fault
42	System always rich	89	Exhaust heat control valve circuit fault
43	EGO cooldown occurred	91	Right EGO always lean
44	Air management system inoperative	92	Right EGO always rich
45	Air always upstream	93	Right EGO cooldown occurred
46	Air not always bypassed	94	Right secondary air inoperative
47	Up air/lean test always rich	95	Right air always upstream
48	Injectors imbalanced	96	Right air always not bypassed
51	ECT input too high	97	Rpm drop (with fuel lean) but right EGO rich
53	TPS input too high	98	Rpm drop (with fuel rich) but right EGO lean
54	ACT (VAT) input too high		

FIGURE 19-17
Typical EEC-IV service codes. (Courtesy of Ford Motor Co.)

pushed in at the beginning of the engine running portion of the EEC-IV self-test procedure, the first code to appear will be the numeral 20, 30, or 40. To obtain the number of engine cylinders, you multiply the numeral by two and drop the zero.

On an analog voltmeter, the I.D. code is indicated by two, three, or four sweeps of the needle. To determine the number of cylinders in this case, you multiply the number of needle sweeps by two.

Dynamic Response Code

During the engine running portion of the self-test sequence that is covered in the next section, a *dynamic response code* appears in place of a separator code. This code appears as the numeral 10 on a STAR tester or by one sweep of the analog voltmeter needle (see Fig. 19–16).

The dynamic response code signals the technician performing the test to push the throttle to the wide-open position for just an instant. This permits the ECA to check proper movement inside the throttle position (TP) and manifold absolute pressure (MAP) sensors. The technician has 15 seconds to "goose" the engine after the code appears. Otherwise, the ECA provides a Code 77, which is "operator did not do the goose test."

On-Demand Codes

An *on-demand code* indicates there is something wrong somewhere in the EEC-IV system at the time of the self-test procedure. This kind of malfunction is know as a *hard fault.*

Interpreting the Codes

As mentioned, a number of service codes do not indicate a hard or intermittent fault within the EEC-IV system. For example, a Code 11 (system pass) will always indicate the system checks out okay for whatever phase of the self-check procedure is being run at the time. The numerals 20, 30, or 40 are always displayed at the beginning of the engine running portion of the self-test and refer to the number of engine cylinders. Lastly, the numeral 10 is either a separator or dynamic response code.

All other service codes (Fig. 19–17), no matter where they occur during the self-test, will always refer to a specific problem area or component within the system. Each of these service codes has only one interpretation, regardless of engine application. That is, the same code will never mean two different things on two different engines. Lastly, if during the EEC-IV self-test you get any code other than 11, it will be necessary to perform the test procedures listed in the Emission Diagnosis/Engine Electronic Shop Manual for the year of the vehicle being repaired.

19-4 EEC-IV QUICK TEST PROCEDURES

As mentioned, the first step in locating the cause of an engine malfunction is accomplished through the use of a diagnostic routine. The diagnostic routines are designed to help you locate the cause of engine performance-related problems that result from malfunctions other than within the EEC-IV system. Moreover, all items listed on a given routine must be checked and problems corrected before moving on to more advanced EEC-IV diagnostics.

However, usually near the end of a typical diagnostic routine is a step that guides you to turn to the quick test section of the Emission Diagnosis/Engine Electronic Shop Manual for the year of the vehicle being tested. The *quick test* is a functional test of the EEC-IV system consisting of six basic steps. These steps must be followed carefully to avoid incorrect diagnosis or the replacement of non-faulty components. The quick test basic steps include the following:

1. Visual check and vehicle preparation.
2. Equipment hookup, engine warm-up, and initial timing check.
3. Key-on, engine-off test.
4. Computed timing check.
5. Engine running self-test.
6. Continuous self-test.

Visual Check and Vehicle Preparation

Before hooking up any equipment in order to diagnose the EEC-IV system, perform the following visual inspections:

1. Check all vacuum hoses for

a. Correct routing according to the vacuum schematic found on the vehicle emissions decal or in the service manual.

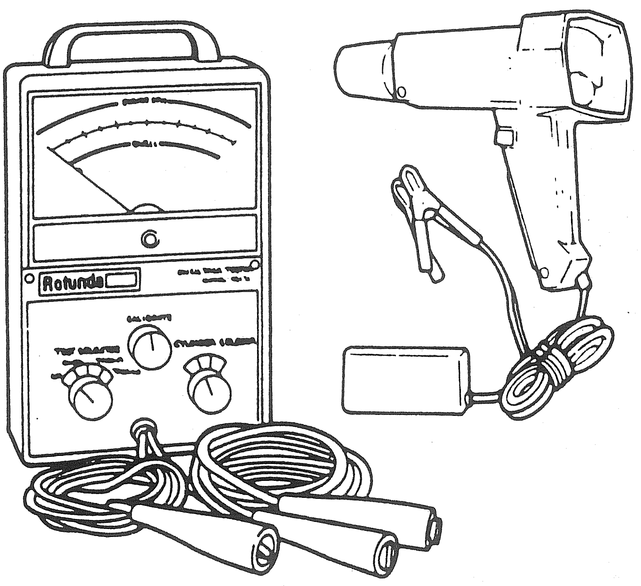


FIGURE 19-18
Tachometer and timing light. (Courtesy of Ford Motor Co.)

b. Clean and tight connections to their respective fittings.

c. Broken, cracked, or pinched hoses or fittings.

2. Verify the condition of the air cleaner and ducting. These components may be removed and reinstalled as necessary for service and inspection.

3. Carefully check the EEC-IV system wiring harnesses for

a. correct matching of male and female connectors.

b. Loose or detached connectors, wires, or terminals.

c. Corrosion at connectors or terminals.

d. Partially broken or frayed wires, particularly at the harness connectors.

e. Shorting between the wiring.

f. Completely broken or detaching wiring.

g. Terminals not completely seated in connectors.

h. Proper routing and position of harnesses. A wiring harness located too close to a high-voltage or high-current cable can pick up erroneous signals. These false signals can cause engine stalling and stumbling. If a microcomputer harness runs parallel to a coil wire, spark plug wires, starter, or battery cables, position it at least five inches from these interference emitters. If a wiring harness must cross such an emitter, it must do so at a right angle to reduce the possibility of signal interference.

Note: It may be necessary to disconnect or disassemble a connector to perform some of the inspections listed here. Before disassembly, be sure to mark the location of each pin. Also, it may be desirable to perform wire continuity measurements while pushing, pulling, or wiggling the harness. Lastly, always probe the connectors from the back (harness side) when making the measurements.

i. Check the ECA, sensors, and actuators for physical damage.

After checking and correcting any problems in the EEC-IV system components listed above, there are also a number of nonrelated parts that should be inspected, if not already done so as part of a diagnostic routine. Although the parts are not related to the operation of the EEC-IV system, it may be necessary to correct faults in them before the system will pass the upcoming self-tests. To make sure these components are serviceable, do the following:

1. Check the distributor cap, rotor, and internal components for damage, corrosion, or signs of excessive wear.

2. Gently shake the PCV valve to make certain it is still operational.

3. Twist the oil filler cap on turbocharged engines to make sure it is tight. A loose cap on turbocharged applications will cause the engine to run rough at idle.

4. Check the condition and level of the engine oil and coolant.

Equipment Hookup

To perform the self-test portion of the quick test, either an analog voltmeter or STAR tester must be connected into the system. Instructions on how to make the hookup of either of these instruments to the vehicle's self-test connector are detailed in Section 19-2 of this chapter.

In addition, you will need to connect a tachometer and timing light to the engine (Fig. 19-18). The tachometer will monitor engine speeds during the

self-test, and it must have a range of 0 rpm to 6,000 rpm, an accuracy of plus or minus 40 rpm, and a resolution of 20 rpm.

The timing light is needed to check initial and computed ignition timing and should be the inductive type. Following manufacturer's instructions, you will connect it to the battery and the No. 1 spark plug wire.

Warming Up the Engine

It is a requirement that the engine be adequately warmed up in order for the self-test to yield accurate information. The ECA as well as the input sensors and output actuators that comprise the EEC-IV system are engineered to self-test at precalibrated engine temperatures. The ECA by itself does not know if the engine is warmed up or not. It depends on signals from the engine coolant sensor for this information.

If the engine coolant along with the EGO sensor have not reached a specified temperature, the ECA will generate incorrect information during the self-test such as Code 21—ECT out-of-range, or Code 41—system always lean.

Moreover, if the engine is warmed up but then allowed to cool off somewhat before the self-test is performed, the microcomputer will generate the service code, Code 43—EGO cool down occurred.

To warm up the engine, run it at fast idle until the thermostat opens. Two things should happen at this point. First, if the engine is so equipped, the electro-drive cooling fan should come on. Second, the upper radiator hose should pressurize and feel hot. If the upper hose is not pressurized and does not feel hot, either the engine has not been running long enough or there is something wrong with the thermostat.

While the engine is running, check the exhaust manifold, EGO sensor, and vacuum hose connections for leaks.

Warning: *Be sure to apply the parking brake, with the transmission in park (neutral for manual transmissions), before running the engine to warm it up.*

Initial Timing Check

The initial ignition timing should be checked during engine warm-up or before the beginning of the self-start sequence. If the initial timing is not within specifications, the computed timing provided for by

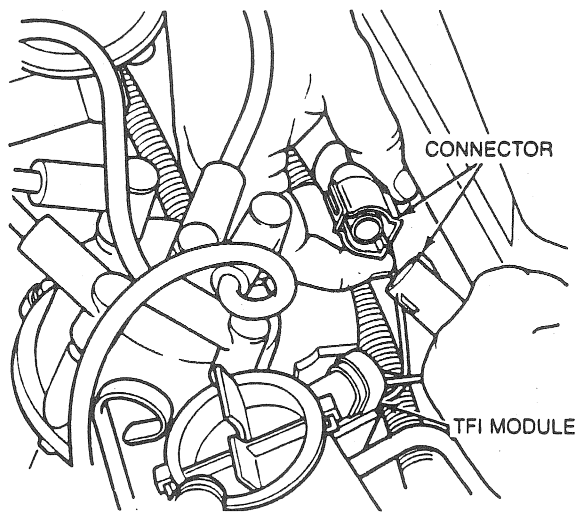


FIGURE 19-19
In-line base timing connector. (Courtesy of Ford Motor Co.)

the ECA will never compensate for the wrong starting point or follow the timing curve programmed into it by the engineers.

To check and adjust the initial timing, do the following:

1. Check the emission control decal for the correct initial timing setting.

2. Locate the in-line timing connector (Fig. 19-19). It is located within six inches of the TFI ignition module, which is mounted to the side of the distributor body.

3. Separate the connector, as shown in Fig. 19-20. This opens the distributor input circuit leading to the ECA and prevents it from sending out timing advance and retard signals to the module.

4. With the engine running at idle, check the initial timing with the timing light.

5. As necessary, loosen and turn the distributor body to obtain the specified initial timing.

6. Tighten the distributor hold-down bolt and reassemble the in-line basic timing connector.

EEC-IV Self-Test

Off and on through this chapter, the self-test sequence has been mentioned several times. *Self-test* is not a conclusive test by itself, but it is used as part of the functional quick test diagnostic procedure. The self-test sequence is an internal function performed by the ECA in which it checks the opera-

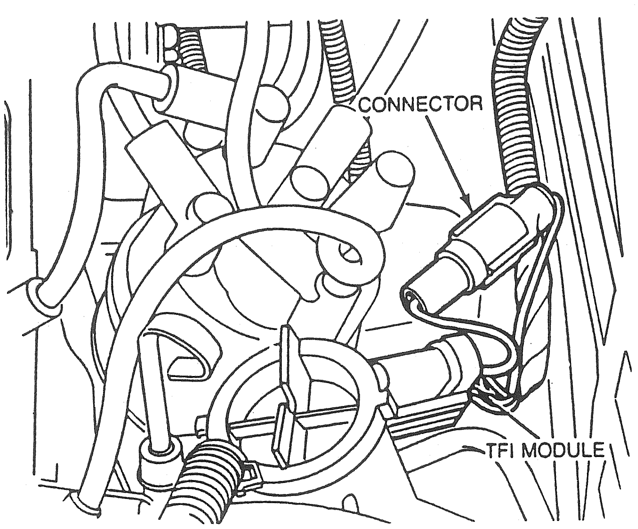


FIGURE 19-20
Disconnecting the in-line base timing connector. (Courtesy of Ford Motor Co.)

tional status of every circuit and component within the EEC-IV system.

The ECA stores the self-test program in its permanent memory. When activated, the program checks the EEC-IV system by testing its memory integrity and processing capability, and it verifies that various sensors plus the actuators are connected and operating properly. Another segment of the self-test allows you to check whether or not the ECA is capable of controlling the ignition timing. This is important because different engine operating modes many times require that the timing be retarded or advanced. The ECA must do this automatically or else the engine will not operate properly under certain conditions.

Just keep in mind that the self-test will not reveal problems that are not directly caused by the EEC-IV system. In other words, it will not tell you if a spark plug is misfiring, there is an open plug wire, the rotor or distributor cap is cracked, or the wrong heat range of spark plugs are installed. These types of problems should have been discovered as a result of using the diagnostic routines.

Key-on/Engine-off Test Sequence

The *key-on/engine-off test* is a functional check that has two primary functions. First, it detects problems (hard faults) that are present at the time of the self-test. Second, the test checks the ECA input sensor signals against stored calibrated values.

Test Procedure with an Analog Voltmeter

To perform the key-on/engine-off self-check with an analog voltmeter, do the following:

1. With the ignition key off, connect the analog voltmeter to the self-test connector as outlined in Section 19-2.

2. Set the voltmeter to read on the 0-volt to 15-volt scale.

3. Turn the ignition switch on.

4. Read and record the service codes as they appear as needle sweeps across the voltmeter scale. Assuming the sensor input signals are within specifications, hard and intermittent service codes should register as follows (Fig. 19-21):

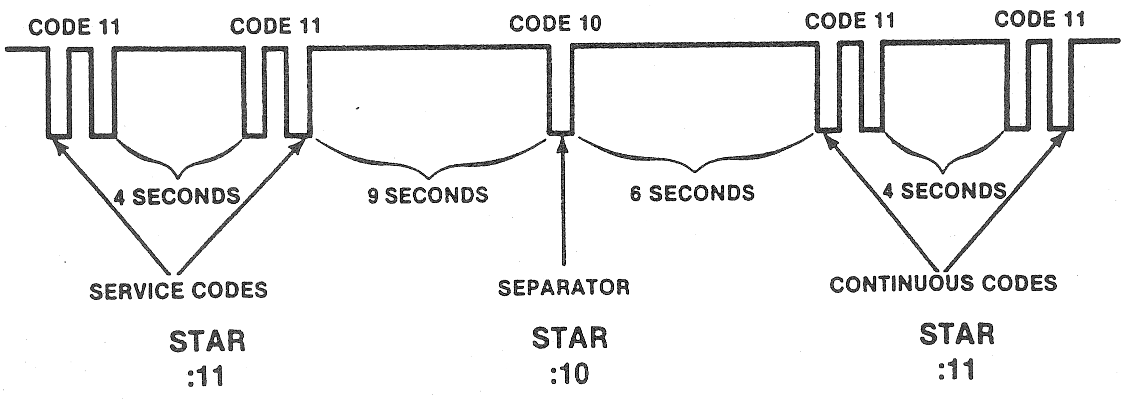


FIGURE 19-21
Key-on/engine-off self-test output code format. (Courtesy of Ford Motor Co.)

a. The needle will fluctuate from zero volts to three or so volts to indicate the fast codes.

b. The needle sweeps twice, with a two-second pause in between. This represents Code 11, system pass. Code 11 will be repeated the second time just in case you missed it the first time. There will be a four-second pause between the two identical codes.

c. A six-second pause comes next, followed by a single sweep of the needle. This represents the separator code. Another six-second pause follows the separator code.

d. Finally, Code 11 is repeated twice again, with a four-second pause in between.

Note: If you obtain any code other than 11 in either the on-demand (hard fault) or memory (intermediate fault) areas of sequence, it will be necessary to proceed with one or more pinpoint tests, as described in the last section, to locate the cause of the problem. Repair all hard faults first before proceeding with the next segment of the self-test. However, do not attempt to repair intermediate faults until after the engine running test sequence has been performed.

Test Procedure Using a STAR Tester

To perform the key-on/engine-off self-test with a STAR tester, do the following:

1. With the ignition key off, connect the STAR tester to the self-test connector following the procedure outlined in Section 19-2.

2. Turn the power switch on the side of the STAR tester to ON.

3. Depress the button in the center of the STAR tester. A colon (:) should appear in the left side of the display readout.

4. Turn the ignition key on. The red LED light on the STAR tester adapter should now come on.

5. If the LED light does not come on, there is an open circuit in the EEC-IV system. In this case, quickly check all the electrical connections for security. If the LED light still does not come on, the ECA will indicate an open circuit as a hard fault during the self-test.

6. If the LED light comes on as a result of on-the-spot tightening or wiggling of harnesses or connectors, the ECA will indicate the open circuit as an intermittent fault during the self-test.

7. Prepare to copy the service codes for reference. The LED light on the STAR tester adapter will also flash off and on as the ECA generates the service codes.

8. If the system checks out okay for hard faults, the first code to appear in the readout window on the STAR tester will be the numeral 11, indicating system pass. Any other codes that appear in the window before the separator Code 10 should be copied down immediately. These codes indicate the existence of a hard fault in one or more of the system inputs (see Fig. 19-21).

9. Separator Code 10 will appear in the readout window when the ECA has stopped checking for hard faults.

10. After the separator code, numeral 11 will appear in the readout window if the system inputs check out okay for intermediate faults. Any other codes that appear in the window should be copied down immediately. These codes indicate there is an intermittent fault stored in ECA memory. The last code to appear in the readout window will remain there until the STAR tester is switched off or until its battery goes dead.

11. Repair all hard faults first before proceeding with the next segment of the self-test. This is accomplished by matching the service codes obtained during this test with a specific pinpoint test found in the Emission Diagnosis/Engine Electronic Shop Manual for the year of the vehicle being tested. Do not attempt to repair immediate faults until after the engine running test sequence has been performed.

Computed Timing Check Using an Analog Voltmeter

To check computed timing when an analog voltmeter is used to monitor the service codes, proceed as follows:

1. With the ignition switch off, unplug the second jumper wire from the self-test connector's Number 2 pin and the self-test input connector (Fig. 19-22).

2. Start the engine and then plug in the

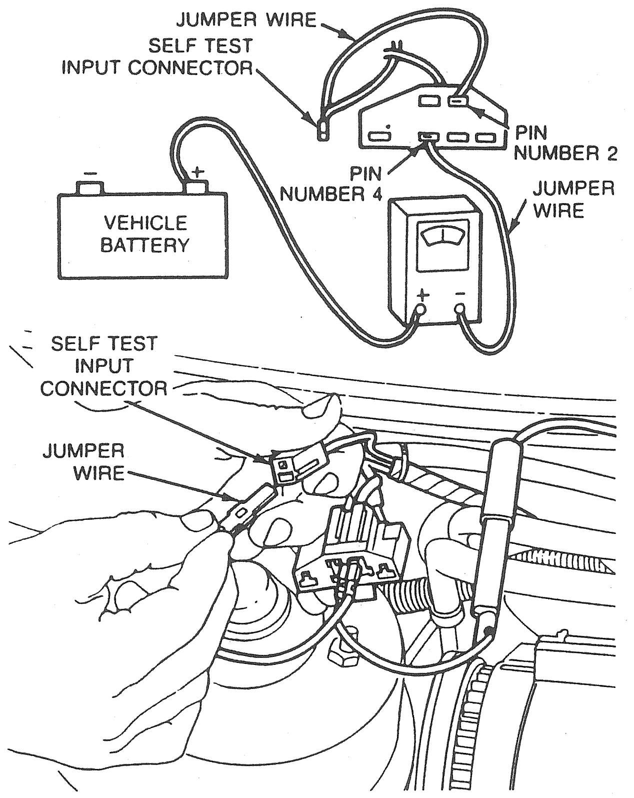


FIGURE 19-22
Plugging and unplugging the jumper wire to the self-test input connector. (Courtesy of Ford Motor Co.)

jumper wire from the self-test connector Number 2 pin to the self-test input connector. You will have two minutes from the time the last code appears to check computed timing.

3. With the timing light, check ignition timing. The timing should read 20 degrees more than initial. For example, if initial timing is 10 degrees BTDC, computed timing should be 10 degrees plus 20 degrees, which equals 30 degrees plus or minus 3 degrees. Ignore all self-test codes during the computed timing check along with the increase in engine speed.

4. If computed timing is not within these specifications, refer to the Emission Diagnosis/Engine Electronic Shop Manual for the year of the vehicle being tested.

5. Shut off the engine and once again unplug the jumper wire as described in Step 1.

6. Remove the timing light.

Computed Timing Check Using a STAR Tester

To check the computed timing when a STAR tester is used to monitor the service codes, do the following:

1. Deactivate the STAR tester by pushing the self-test button up; now the colon should not appear.

2. Start the engine. If the engine does not start, refer to the EEC-IV pinpoint tests for no-start problems, which are found in the Emission Diagnosis/Engine Electronic Shop Manual for the year of the vehicle being tested. Repair defects as necessary before proceeding.

3. With the engine running, depress the self-test button on the STAR tester. At this point, engine speed should increase. Ignore any service codes that appear in the readout window.

4. Check the computed timing with a timing

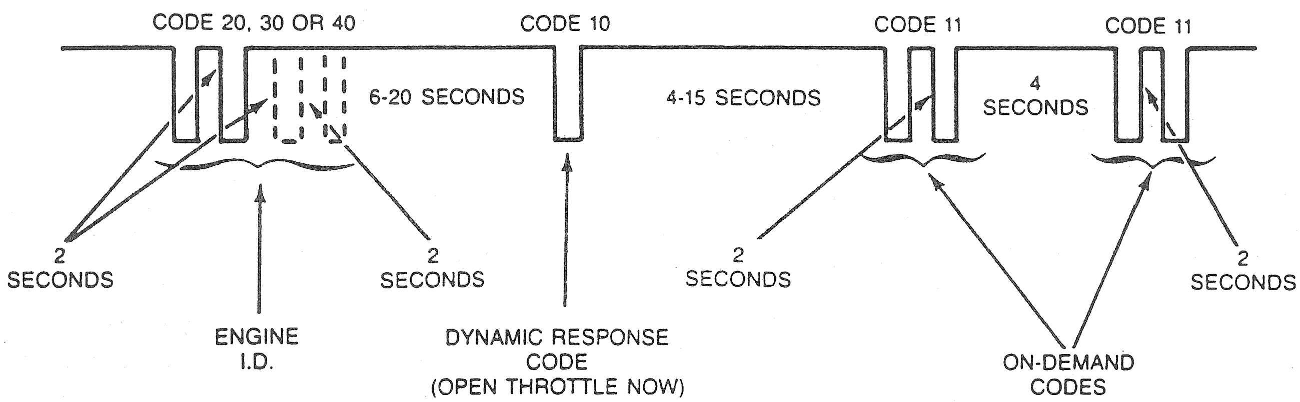


FIGURE 19-23
Analog voltmeter engine running output service code format. (Courtesy of Ford Motor Co.)

light. The self-test sequence and ignition timing lock remain activated for only two minutes. While in the self-test sequence, ignition timing should read 20 degrees plus or minus 3 degrees more than initial. If not, refer to the Emission Diagnosis/Engine Electronic Shop Manual for the vehicle being tested.

5. Deactivate the STAR tester by once again depressing the self-test button. The colon should disappear along with any displayed service codes. In addition, the engine speed should decrease.

6. Turn the ignition switch off.

7. Remove the timing light.

Engine Running Test Sequence Using an Analog Voltmeter

To perform the engine running test sequence while monitoring the service codes with an analog voltmeter, do the following:

1. Start the engine and operate it at about 1,500 rpm for two minutes to warm up the EGO sensor.

2. Turn the engine off.

3. Plug in the jumper wire to the self-test input connector as shown in Fig. 19–22. Wait ten seconds.

4. Start the engine.

5. Assuming the system checks out satisfactorily for hard faults, the service codes should register as follows (Fig. 19–23):

a. The needle will sweep two, three, or four times without a pause, depending on the number of engine cylinders.

b. After a six- to 20-second pause, the needle will sweep once. This is the dynamic response Code 10, which indicates you have 15 seconds to goose the throttle to the wide-open position.

c. A 4- to 15-second pause follows the goose test. The needle then fluctuates from zero volts to three volts to indicate the fast codes.

d. The needle will sweep twice with a two-second pause in between, representing Code 11. After four seconds, the same code is repeated. If you do not goose the engine within 15 seconds from the time the dynamic response code appears, the needle will sweep twice seven times with a two-second pause in between. This represents a Code 77, "operator did not do goose test."

6. If any on-demand code other than 11 appears during Step 5, follow the test instructions found in the Emission Diagnosis/Engine Electronic Shop Manual for year of the vehicle you are testing.

Engine Running Test Sequence Using a STAR Tester

To perform the engine running test sequence using a STAR tester to monitor the service codes, do the following:

1. Start and run the engine at about 1,500 rpm for two minutes to warm up the EGO sensor.

2. Turn the engine off and depress the self-test button on the STAR tester. The colon should appear in the readout window.

3. Wait 10 seconds and then start the engine.

4. Observe the service codes that appear on the STAR display.

a. The first code to appear should be an engine identification code, either 20, 30, or 40 (Fig. 19–24).

b. After a six- to 20-second pause, the dynamic response Code 10 appears in the readout window. You now have 15 seconds to move the throttle to the wide-open position for an instant. Let it return immediately to the idle position.

c. A 4- to 15-second pause follows the goose test. Next, the fast codes appear as a slight flicker of the LED light on the STAR tester adapter.

d. If the system checks out okay, a Code 11 will appear in the readout window twice with a two-second pause between them. If you did not goose the engine within 15 seconds from the time the dynamic response code appears, a Code 77 will appear in the window indicating that the operator did not do the goose test.

5. Any other codes appearing in Step 4(d) should be copied down immediately. These codes in-

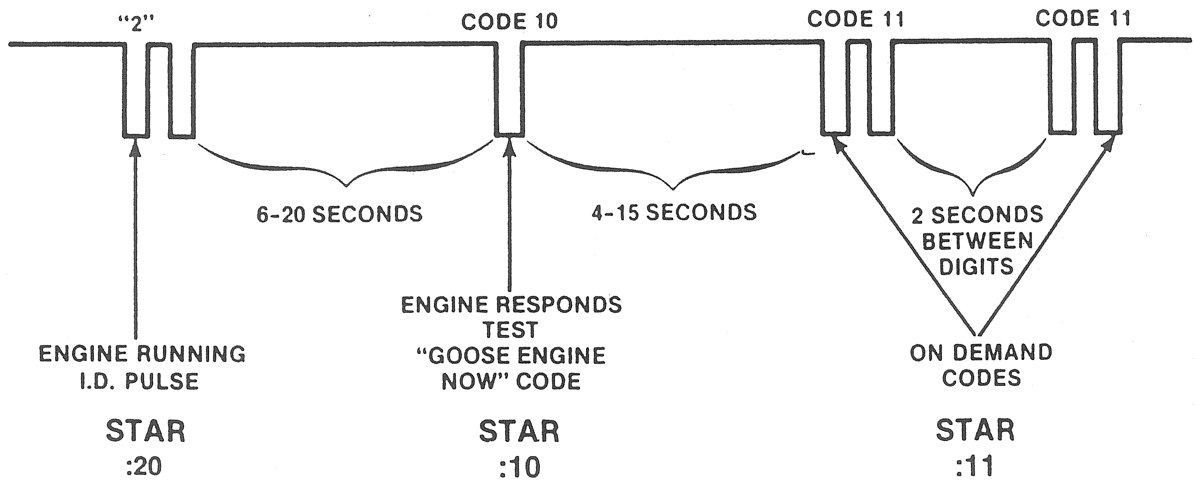


FIGURE 19-24
STAR tester engine running output code format. (Courtesy of Ford Motor Co.)

dicate the existence of a hard fault in one or more of the system output components. Repeat this segment of the self-test to verify these codes.

6. Repair all of the hard faults according to the procedures found in the Emission Diagnosis/Engine Electronics Manual for the year of the vehicle you are testing.

Continuous Monitor Test

The ECA continually looks for short or open circuits and other intermittent faults within the EEC-IV system. Moreover, the ECA stores them in memory as continuous codes when they occur. These continuous codes are obtained from memory during the key-on/engine-off segment of the self-test.

The *continuous monitor test* is intended as an aid in diagnosing intermittent faults and is run either with the engine off or running with either an analog voltmeter or STAR tester attached to the self-test output connector. To perform the key-on/engine-off continuous monitor test, do the following:

1. Repeat the key-on/engine-off self-test to confirm if a continuous code is still in memory.

2. Turn the ignition switch off, and either remove the jumper wire from the self-test input connector (see Fig. 19-22) or push up the STAR tester self-test button. Either action will deactivate the self-test sequence and activate the continuous monitor test. Turn the ignition switch on.

3. Now attempt to recreate the problem by performing the intermittent fault confirmation check. This is done by

a. Wiggling connectors and harnesses.

b. Manipulating moveable sensors or actuators.

c. Heating thermistor-type sensors with a heat gun.

Note: Suspect components such as sensors, actuators, and harnesses are identified by matching the continuous service codes obtained during the key-on/engine-off segment of the self-test. For example, a continuous Code 51 indicates a problem with the ECT sensor or its wiring harness.

4. When the intermittent fault is recreated, the voltmeter needle will sweep back and forth across the scale or sweep to the right and stay there. The STAR tester LED will flicker or go out altogether.

The *engine running continuous monitor test* can be entered in one of two ways. First, the monitor test will automatically start about two minutes after the service codes from the engine running portion of the self-test are stored in memory. This is due to the fact that the engine self-test will only activate once per ignition cycle.

The second and quickest way is to deactivate the running self-test sequence by completing Step 2 in the key-off procedure. However, do not shut the engine off.

In either case, an intermittent fault will be recreated and indicated in the same way as it would during the key-on/engine-off continuous monitor test. Any malfunctioning components identified in this fashion can be repaired or replaced without fur-

ther diagnostic testing. However, any intermittent faults that cannot be recreated by the above method must be diagnosed and repaired using the appropriate pinpoint tests, which can be found in the Emission Diagnosis/Engine Electronic Shop Manual for the vehicle being tested.

Output Cycling Test

Another test that is helpful during diagnosis is the *output cycling test.* This test enables you to energize and de-energize most of the system output actuators on command. This is performed during the key-on/engine-off self-test sequence after any continuous codes have been set. To perform this test, do the following:

1. Without disabling the self-test sequence, momentarily depress the throttle to the floor and release it. This will energize most of the EEC-IV actuators, and solenoid armatures should move open or close accordingly.

2. Another throttle depression will de-energize the actuators and solenoids.

3. Repeat the process as many times as necessary.

4. Malfunctioning components identified in this manner should be repaired or replaced.

Erasing Memory Codes

You can erase service codes from ECA memory by doing the following:

1. Turn the ignition key off.

2. Deactivate the STAR tester by depressing its self-test button. The colon should disappear from the readout window. Or, remove the jumper wire used with an analog voltmeter from the self-test input connector.

3. Turn the ignition switch on.

4. Reactivate the STAR tester by depressing the self-test button, or plug the jumper wire into the input self-test connector.

5. As soon as either instrument begins to display a service code, even Code 11, deactivate the self-test sequence by depressing the STAR self-test button or unplugging the jumper wire. Any memory codes held in storage should be erased at this time.

6. Verify that memory codes have been erased by turning the ignition switch off and repeating Steps 3 and 4 above.

Note: Never erase intermittent faults from memory until they have been repaired.

19-5 PINPOINT TEST ROUTINES

As mentioned, there is an Emission Diagnosis/Engine Electronic Shop Manual (Volume H) published yearly for Ford-built vehicles. This manual has sections devoted entirely to diagnostic and repair procedures for all engines equipped with the EEC-IV system. A subsection in the manual entitled Quick Tests contains instructions for performing the self-test, as outlined in this chapter.

In the event that the self-test uncovers an EEC-IV malfunction, there are also instructions for locating specific *pinpoint test routines.* These assist you in isolating and repairing the exact cause of the problem that is producing the service code received.

Before discussing how to locate and use an actual pinpoint test routine, there are some specific instructions you must follow.

1. Do not run any pinpoint test unless you are instructed to by a Quick Test Procedure. Each pinpoint test assumes that a fault has been detected within the system and directs you to follow a specific repair routine. *Performing any pinpoint test without being told to by a Quick Test may produce incorrect results and result in the replacement of serviceable parts.*

2. Do not replace any parts unless the test results indicate they are defective.

3. When more than one service code is received, always start the repair with the first code received.

4. Do not measure voltage or resistance at the ECA or connect any test lights to it unless specifically told to.

5. Unless specified not to, isolate both ends of a circuit and turn the ignition switch off whenever checking for shorts or continuity.

6. Disconnect solenoids and switches from the harness before measuring for continuity and resistance, or before energizing by means of a 12-volt source.

7. In using the pinpoint tests, always follow each step in order, starting at the first step and following the remaining ones until the fault is found. Never skip any of the steps.

8. An open is defined as any resistance reading greater than 5 ohms unless otherwise specified.

9. A short is defined as any resistance reading less than 10,000 ohms to ground, unless specified otherwise.

10. After completing any repairs in the EEC-IV system, verify that all components are properly reconnected and repeat the self-test sequences.

With these instructions in mind, let's run through the process of locating the cause of a specific problem using the Quick Test and Pinpoint Test subsections of the Emissions Diagnosis/Engine Electronic Shop Manual. First, let us assume you have completed the quick test in its correct sequence and have received an on-demand service Code 21 during the key-on/engine-off self-test (Fig. 19-25). Note in the illustration that Code 21 is the second one listed under the Result Column. In this case, the Action to Take Column tells you to go to Pinpoint Test Step DE1.

The pinpoint test itself (Fig. 19-26) has a three-column format. The left column explains how to perform a given test procedure. The center column details what the results should be, while the right one explains the action to take to correct the problem. The key point to remember again is that you must follow the steps in the order given. If this is done, you will locate the cause of the problem in the shortest amount of time without damaging or replacing otherwise serviceable system components.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. Explain the function of the pinpoint tests and where they are found [19-5].
2. What are the important points to remember before assuming the microcomputer system is the cause of the engine malfunction [19-1]?
3. What are the six basic steps in performing a EEC-IV quick test [19-4]?
4. What is a service code [19-2]?
5. What are the six types of service codes [19-3]?

REVIEW

1. Which test routine is completed first after the diagnostic [19-5]?
   Technician A says the pinpoint.
   Technician B states the quick.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
2. The EEC-IV self-test will not show up what type of defect [19-1]?
   a. a misfiring spark plug
   b. a cracked rotor
   c. both a and b
   d. neither a nor b
3. The continuous monitor test is an aid in finding the cause of what type of fault [19-4]?
   Technician A says an intermittent fault.
   Technician B states a hard fault.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
4. If the LO BAT message appears on the STAR display while checking out the meter, what must be done [19-2]?
   a. Replace the meter's nine-volt battery.
   b. Recharge the vehicle's battery.
   c. both a and b
   d. neither a nor b

3.1	KEY ON, ENGINE OFF SELF-TEST

- Using the On Demand Service Codes from Key On, Engine Off Quick Test Step [3.0] follow the instructions in the Action To Take column in this Step.
- When more than one service code is received, always start service with the first code received.
- Whenever a repair is made, REPEAT Quick Test.

NOTE: **Before proceeding to the specified Pinpoint Test, read the instructions on how to use the Pinpoint Tests at the beginning of the Pinpoint Test section.**

RESULT		ACTION TO TAKE
ON DEMAND SERVICE CODES		
15	▶	REPLACE processor. REPEAT Quick Test.
21	▶	GO to Pinpoint Test Step [DE1].
22	▶	GO to Pinpoint Test Step [DF4].
23	▶	GO to Pinpoint Test Step [DH1].
24	▶	GO to Pinpoint Test Step [DB1].
31	▶	GO to Pinpoint Test Step [DL40].
51	▶	GO to Pinpoint Test Step [DE10].
53	▶	GO to Pinpoint Test Step [DH20].
54	▶	GO to Pinpoint Test Step [DB10].
61	▶	GO to Pinpoint Test Step [DE20].
63	▶	GO to Pinpoint Test Step [DH30].
64	▶	GO to Pinpoint Test Step [DB20].
81	▶	GO to Pinpoint Test Step [UA1].
82	▶	GO to Pinpoint Test Step [UA1].

FIGURE 19-25
Typical quick test procedure. (Courtesy of Ford Motor Co.)

TEST STEP	RESULT ▶	ACTION TO TAKE
DE1 SERVICE CODE 21: CHECK ENGINE OPERATING TEMPERATURE		
• Run engine for 2 minutes at 2,000 rpm. • Check that upper radiator hose is hot and pressurized. • Rerun Quick Test.	Vehicle stalls ▶	Do not service code 21 at this time, REFER to diagnosis by symptoms.
	Code 21 present ▶	GO to $\boxed{\text{DE2}}$.
	Code 21 not present ▶	SERVICE other codes as necessary.
DE2 CHECK ECT AND SIG. RTN. VOLTAGE		
• Key Off, wait 10 seconds. • Disconnect harness from ECT sensor. Inspect for damaged pins, corrosion, loose wires, etc. Service as necessary. • DVOM on 20 volt scale. • Key On, Engine Off. • Measure voltage between ECT sensor harness connector ECT signal to signal return.	Reading is between 4.0V and 6.0V ▶	GO to $\boxed{\text{DE5}}$.
	Reading is less than 4.0V ▶	GO to $\boxed{\text{DE3}}$.
	Reading is greater than 6.0V ▶	GO to Pinpoint Test Step $\boxed{\text{C1}}$.
DE3 CHECK CONTINUITY OF ECT SIG. AND SIG. RTN.		
• Key Off, wait 10 seconds. • Harness disconnected from ECT sensor. • Disconnect processor 60 pin connector — inspect for damaged pins, corrosion, loose wires, etc. Service as necessary. • Install Breakout box to harness. Leave processor disconnected. • DVOM on 200 ohm scale. • Measure resistance of ECT sensor harness connector ECT signal to test Pin 7. • Measure resistance of ECT sensor harness connector Signal Return to test Pin 46.	Both readings are less than 5 ohms ▶	GO to $\boxed{\text{DE4}}$.
	Either reading is 5 ohms or greater ▶	SERVICE circuit opens. REMOVE Breakout box. RECONNECT processor and ECT sensor. RERUN Quick Test.

FIGURE 19-26
Typical pinpoint test procedure. (Courtesy of Ford Motor Co.)

5. At the end of the key-on/engine-off self-test, repair all [19-4]
   Technician A states intermittent faults.
   Technician B replies hard faults.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
6. If a malfunction occurs in an engine equipped with an EEC-IV system, the first thing to do is perform [19-1]
   a. a diagnostic routine.
   b. a quick test.
   c. both a and b
   d. neither a nor b
7. To check initial timing, disconnect [19-4]
   Technician A replies the self-test input connector.
   Technician B states the in-line timing connector.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
8. In what form does the ECA generate a service code [19-2]?
   a. as a three-digit timed electrical pulse
   b. as a two-digit timed electrical pulse.
   c. both a and b
   d. neither a nor b
9. If an engine is not warmed up properly before the self-test, the ECA will generate what code [19-4]?
   a. 21
   b. 41
   c. 11
   d. both a and b
10. In order to read a service code, an analog voltmeter or STAR tester must be connected to [19-2]
    Technician A replies the self-test input connector.
    Technician B states the ECA input harness.
    Who is correct?
    a. A only
    b. B only
    c. both a and b
    d. neither a nor b
11. Whenever possible, a microcomputer harness should never be located close to [19-4]
    a. a high-voltage cable.
    b. a high-current cable.
    c. both a and b
    d. neither a nor b
12. What is the pause between each service code digit on an analog voltmeter [19-2]?
    a. six seconds
    b. four seconds
    c. two seconds
    d. one second
13. A Code 77 indicates what problem [19-3]?
    Technician A states that the operator did not do the goose test.
    Technician B says that there was no TP sensor change during the goose test.
    Who is correct?
    a. A only
    b. B only
    c. both a and b
    d. neither a nor b
14. An intermittent fault is stored in the form of [19-3]
    a. an on-demand code.
    b. a continuous code.
    c. both a and b
    d. neither a nor b
15. Which code is not used by the technician [19-3]?
    a. fast
    b. continuous
    c. identification
    d. both a and c

Chapter 20

TYPICAL GENERAL MOTORS COMPUTERIZED ENGINE CONTROL SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- describe the function and design of the computer command control (CCC)-carbureted system.
- explain the basic operation of the CCC system in open and closed loop.
- identify and know the function of the components within a CCC throttle body injection (TBI) system.
- explain the basic operation of the CCC-TBI system.
- identify and know the function of the components within the CCC port fuel injection (PFI) system.
- describe the operation of the CCC-PFI system.

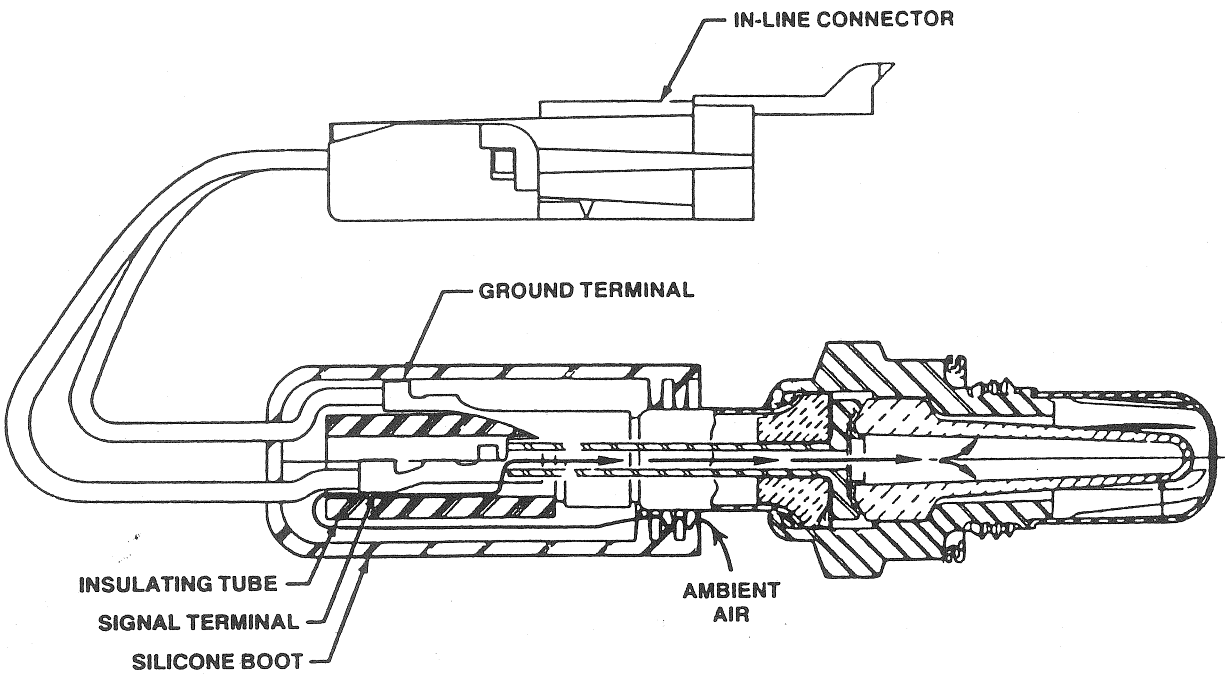


FIGURE 20-1
Oxygen sensor. (Courtesy of General Motors Corp.)

In 1979, General Motors introduced its first comprehensive computerized engine control system on selected applications. This system was called the computer-controlled catalytic converter (C-4). Since that time, GM has not only updated and renamed this system for carbureted engines but also developed systems designed for use with throttle body and port injection.

It would be impossible to cover the various versions of the GM computerized systems in detail within the space constraints of this chapter. For this reason, only overviews of the CCC-carbureted, CCC-TBI, and CCC-PFI systems are provided to familiarize you with them.

Before beginning the study of GM computerized systems, there is one important fact to remember. Previous chapters have already provided a lot of information about a number of components you are about to study. If at any time there is a point you do not understand, use the index or table of contents, and go back and restudy the subject material found in earlier chapters of the text.

20-1 COMPUTER COMMAND CONTROL SYSTEM INPUTS

General Motors introduced the *computer command control (CCC)* system in mid-1980. By 1981, all GM carbureted passenger cars came equipped with this system. However, there are differences within the CCC system from one engine application to another and between various model years. In any case, the purpose of the CCC system is the same; that is, to control harmful emissions, improve fuel economy, and enhance driveability.

Like the Ford systems described in Chapter 18, the CCC system has a number of system input devices. These sensors and switches provide input data to the microcomputer relative to such factors as air/fuel ratio, engine load and speed, coolant temperature, vehicle speed, transmission operating range, and atmospheric or altitude changes. While some of the devices described in this section will be found on all systems, some are used on only a few applications.

Oxygen Sensor

The *oxygen sensor* (Fig. 20-1) is located within the exhaust manifold and is a closed-end, zirconia, voltage-generating device. In operation, the sensor compares the oxygen content in the exhaust gases to that within the outside air. The unit then generates a voltage signal to the microcomputer (electronic control module) that reflects the difference in oxygen levels. This signal is utilized by the microcomputer to control the engine's air/fuel ratio. How-

ever, before the sensor can produce a voltage that is usable by the microcomputer, it must be at an operating temperature of 600°F (315°C).

The voltage output of a normal operating oxygen sensor fluctuates rapidly back and forth between about 0.1 and 0.9 volt. However, whenever the oxygen content is high, indicating a lean air/fuel mixture, the sensor voltage output will always be below 0.45 volt. On the other hand, if the air/fuel mixture is rich (low exhaust oxygen content), the sensor voltage is always above approximately 0.45 volt.

Three types of sensors are in use: the single-, double-, and triple-wire assemblies. The single-wire sensor assembly grounds through its physical contact with the exhaust manifold. With the two-wire arrangement, the second wire provides a back-up ground through the microcomputer. The triple-wire sensor also grounds both ways, but it also has a third wire that provides power to an integral preheater.

Coolant Temperature Sensor

The *coolant temperature (CT) sensor* threads into the water jacket of the engine (Fig. 20-2). This sensor produces a voltage signal that the microcomputer can use to vary the air/fuel ratio as the engine coolant temperature changes from cold to normal; to accomplish various switching functions, such as EGR and EFE, at different temperatures; to provide a switch point for the hot temperature light indication on some systems; to alter the amount of spark advance; to vary the idle speed; and to change the microcomputer operating mode from open to closed loop.

The CT sensor is a thermistor-type sensor. As such, its internal resistance varies with changes in coolant temperature. For example, with increases in coolant temperature, CT sensor resistance decreases. Resistance increases as temperature goes down.

The microcomputer sends a five-volt reference signal to the CT sensor. This reference signal is then altered by the internal resistance of the sensor before going back to the microcomputer. For instance, when coolant temperature is low, CT sensor resistance is high, and a low voltage signal is sent back to the microcomputer. On the other hand, high coolant temperature lowers CT sensor resistance, and a higher voltage signal is sent out.

Throttle Position Sensor

The *throttle position (TP) sensor* mounts within the

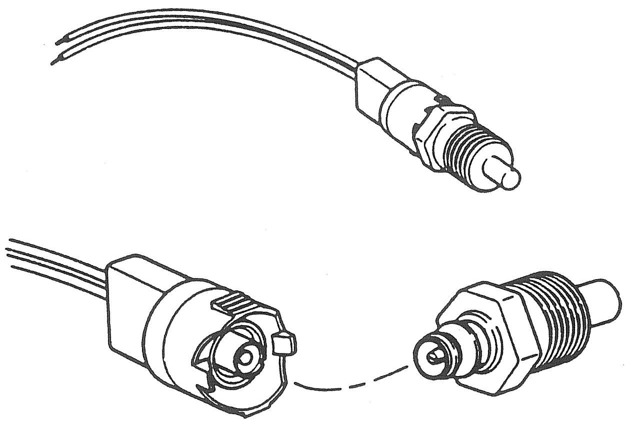


FIGURE 20-2
Typical CTS. (Courtesy of General Motors Corp.)

carburetor float bowl (Fig. 20-3). The sensor consists of an adjustable potentiometer (variable resistor) that has a moveable wiper plunger operated by the accelerator pump lever.

As in the case of the CT sensor, a five-volt reference signal is supplied by the TP sensor by the microcomputer. From this, the TP sensor develops and directs back to the microcomputer a varying signal based on throttle position. At closed throttle, for example, the TP sensor signal is about one volt or less. But as the throttle opening increases, the signal raises to about five volts at wide-open throttle.

The microcomputer can use the TP sensor signal to regulate a number of functions. These include the mixture control solenoid, idle-speed control, and torque converter clutch.

Pressure Sensors

There are three different types of pressure sensors used on the various CCC systems: the manifold absolute, barometric pressure, and pressure differential. All of these units are nearly identical in appearance and are the piezoresistive type (Fig. 20-4).

The sensor incorporates a square silicone chip. Along the outer edges, the chip is about 2.50 millimeters thick, while at the center its thickness is only 0.25 millimeter. The difference in thickness forms a diaphragm. In addition, the edge of the chip is sealed to a pyrex plate under a vacuum, thereby forming a differential pressure chamber between the plate and the center areas of the silicone chip.

A set of sensing resistors is formed around the edge of this chamber. The resistors are formed by diffusing a doping impurity into the silicone. External connections to the resistors are made through

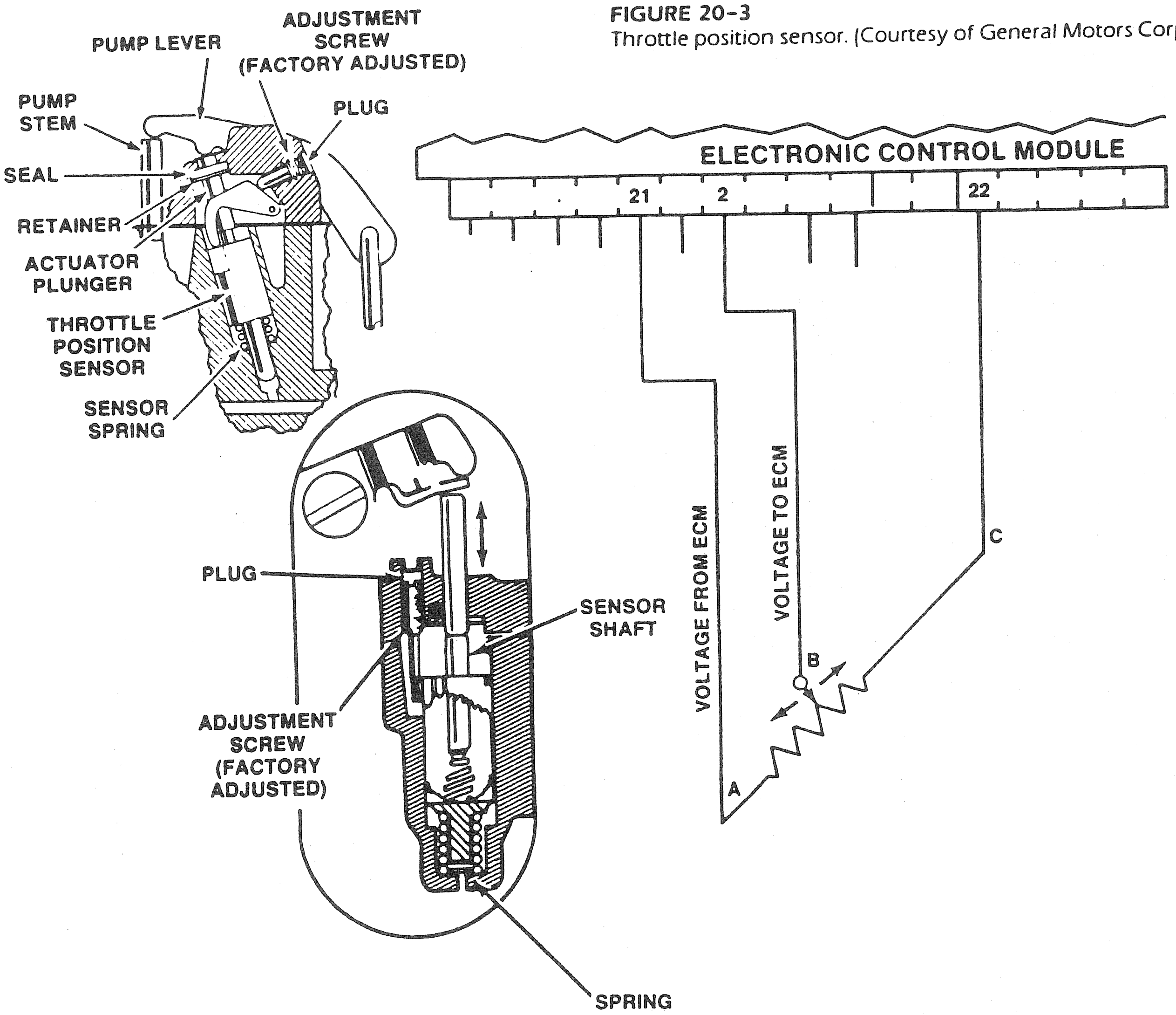


FIGURE 20-3
Throttle position sensor. (Courtesy of General Motors Corp.)

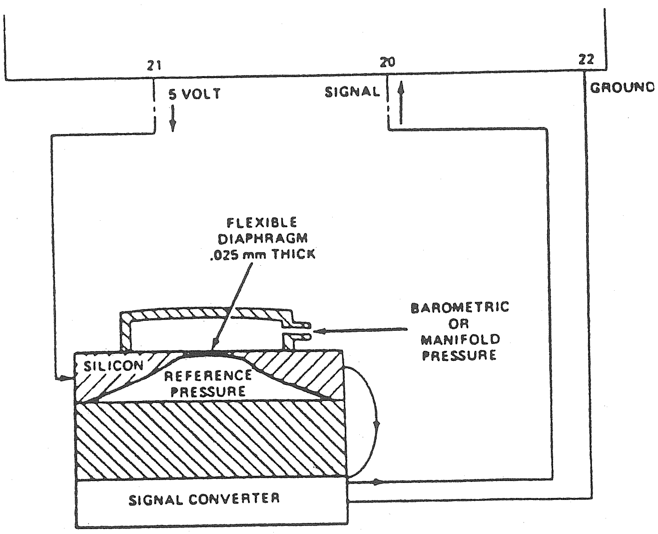


FIGURE 20-4
Design of a pressure sensor.

wires connected to metal bonding pads.

The entire assembly is placed within a sealed housing with a small diameter tube. It is used either as an atmosphere port or to connect the sensor to the intake manifold.

In operation, a difference in pressure causes the diaphragm to deflect. As a result, the resistance of the sensing resistors changes in proportion to the difference in pressure by a phenomenon known as piezoresistivity. This occurs in certain semiconductors due to a fractional change in length of the material due to the strain of flexing.

As shown in Fig. 20-4, the microcomputer directs a reference voltage of five volts to one edge of the semiconductor material. On the opposite edge is the output signal terminal to the signal converter. As the diaphragm flexes due to the reference pres

sure on one of its sides and either barometric or manifold pressure on the other, the amount of resistance changes between the two terminals.

This has the effect of varying the signal to the converter. The *signal converter* is a differential amplifier that generates a signal to the microcomputer that is proportional to the difference between the input reference voltage and the voltage entering the converter from the sensor.

Devices such as these that use a reference pressure are known as *absolute sensors*. The two absolute sensors used on CCC systems are the manifold absolute and barometric pressure.

Manifold Absolute Pressure Sensor. The *manifold absolute pressure (MAP) sensor* develops a voltage signal based on changes in intake manifold vacuum that result from engine load and speed changes. The sensor, in effect, measures the amount of absolute pressure in the manifold, which is atmospheric pressure minus manifold pressure.

When manifold absolute pressure increases (vacuum decreases), the MAP signal to the microcomputer rises. But if the absolute pressure decreases (vacuum increases), the sensor signal is reduced in strength. The microcomputer uses the sensor signals to adjust the air/fuel ratio and ignition timing for various operating conditions.

Barometric Pressure Sensor. The *barometric pressure (BARO) sensor* monitors ambient and barometric pressure and can be used along with a MAP sensor. The BARO sensor provides the microcomputer with a signal based on ambient pressure changes due to weather or altitude.

With increases in altitude, for instance, the signal voltage decreases. This reduction in the voltage signal causes the microcomputer to lean out the air/fuel ratio without any change in throttle position, ignition timing, or both for good engine performance and reduced exhaust emissions at higher altitudes.

Vacuum Sensor. A *vacuum sensor* is the differential pressure type. That is, it compares manifold vacuum to atmospheric pressure. When the vacuum sensor is used, there is no need for a BARO sensor since the vacuum sensor is always comparing manifold vacuum to atmospheric pressure.

The vacuum sensor is manufactured like the absolute sensors just described except the former has a second port opening. This port opening permits atmospheric pressure to enter what was the reference pressure cavity of the absolute-type units.

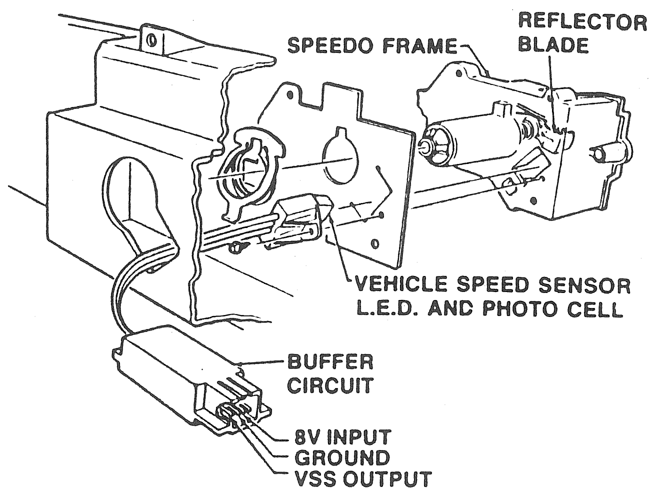


FIGURE 20-5
Typical VS sensor design. (Courtesy of General Motors Corp.)

With this design, when engine vacuum exerts itself on one side of the diaphragm and atmospheric pressure on the other, the diaphragm deflects, causing a change in resistance.

As a result, the sensor produces a voltage signal that is proportional to atmospheric pressure and changes in engine vacuum. However, just opposite to the MAP sensor output, the vacuum signal voltage goes up with increases in engine vacuum. With a closed throttle and high engine vacuum, the signal is about five volts.

Vehicle Speed Sensor

The *vehicle speed (VS) sensor* is a pulse counter sensor that informs the microcomputer how fast the vehicle is being driven. In the CCC system, the microcomputer uses this information for operation of the torque converter clutch.

The speed sensor consists of a light-emitting diode (LED) and a phototransistor (Fig. 20-5). Both of these components are housed in a plastic connector that plugs into the back of the speedometer housing next to the speedometer cable. A wiring harness connects the sensor to the microcomputer.

Before 1982, the LED was energized by eight volts from the microcomputer. After that, the voltage was raised to 12 volts.

In any case, the light-emitting diode is lit whenever the ignition switch is turned on. However, the light given off by the diode is in the infrared area of the light spectrum that is not visible to the human eye. The LED light is directed back toward the back of the speedometer cup that is painted black.

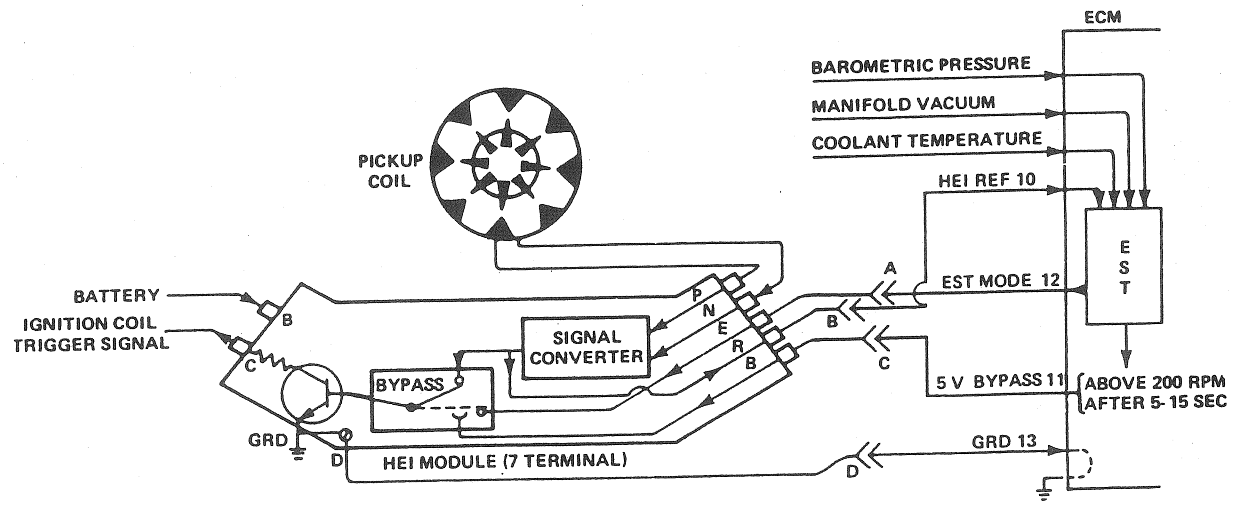


FIGURE 20–6
High energy ignition (HEI) reference signal. (Courtesy of General Motors Corp.)

The drive magnet, which is part of the speedometer rotating component, has blades with a reflective surface. As each blade of the drive magnet passes in front of the LED light beam, it is reflected back to the phototransistor. The phototransistor then generates a DC analog signal, which varies both in amplitude and frequency, to the buffer circuit.

The buffer circuit has two functions. First, it amplifies the weak phototransistor signal. Second, it changes the analog signal into digital pulses that the microcomputer interrupts as vehicle speed in miles per hour.

Engine Speed Signal

The microcomputer receives crankshaft speed and position signals by means of the *distributor reference pulses* or *high energy ignition (HEI) REF signal* (Fig. 20–6). As shown in the illustration, the signal is taken off connector Terminal R on the HEI module.

The reference signal originates at the distributor pickup coil. When the engine is cranking over or running, the distributor shaft and timer core rotate past the pole piece and pickup coil. As the teeth on the timer core align and misalign with those on the pole piece, a voltage signal is induced into the pickup coil.

This AC signal then passes to the signal converter within the HEI ignition module. The signal converter changes the AC analog signal from the pickup coil to a digital signal that the microcomputer can use.

During engine cranking and under some failure conditions, the pickup coil signal is utilized to turn off the main switching transistor in the HEI module. This has the effect of breaking the primary coil circuit. However, under normal operating conditions, the pickup coil signal is converted, as mentioned, and used to signal crankshaft speed and position to the microcomputer.

From 1982 to 1985, a Hall-effect switch instead of the pickup coil was used to create the HEI REF signal on 3.8-liter V-6 engines (Fig. 20–7). The Hall-effect switch produces greater timing accuracy on these odd-firing engines due to the differences in cylinder-to-cylinder top dead center (TDC) points.

Note in Fig. 20–7 that the distributor still has the pickup coil. However, it is only used to provide the HEI module switching transistor with signals during engine starting. In addition, Terminal R on the HEI connector is not used.

The Hall-effect switch assembly mounts within the distributor above the normal pickup. The assembly consists of the permanent magnet that is very close to the Hall-effect element. Operating in the air space between the two parts are vanes attached to the rotor. The vanes alternately cut off and pass the field from the magnet to the Hall-effect element. When the field passes through the element, a digital signal is produced in it.

The Hall-effect signal passes to the base circuit of a transistor. The collector of the transistor connects via a resistor to a 12-volt source that is provided by the microcomputer. Moreover, the HEI REF signal line also attaches to the collector. The

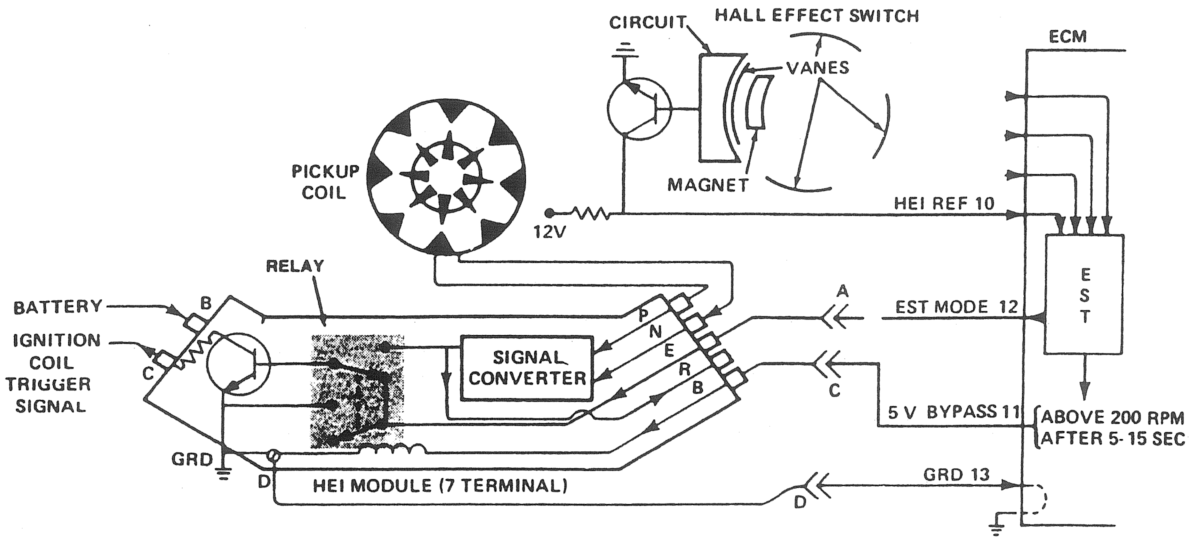


FIGURE 20–7
Hall-effect reference signal. (Courtesy of General Motors Corp.)

emitter connects to ground as shown in Fig. 20–7.

When the space between two vanes permits magnetism to reach the Hall-effect element, a voltage is produced in it that turns the transistor on. With the transistor on, the HEI REF signal drops to one volt, which is the voltage drop across the transistor.

As a vane blocks the magnetic field from the element, there is no voltage produced, and the transistor turn off. Now the HEI REF voltage becomes 12 volts. However, with the engine running, the HEI REF voltage will average out to be about six volts.

Throttle Switch

A *throttle switch* or *nose switch* is incorporated into the end of the idle speed motor actuator. The position of this switch determines whether the microcomputer controls idle speed or not. When the throttle is closed at idle, for example, the switch signals the microcomputer to energize the motor (Fig. 20–8). The motor, in turn, adjusts the idle speed to the proper amount.

When the throttle is moved off idle, the throttle switch opens. As a result of the open switch signal, the microcomputer extends the actuator and then stops sending idle speed commands. At this point, the driver controls engine speed.

Air Conditioning Clutch Switch

An *air conditioning clutch switch* is mounted in the air conditioner compressor. This on/off switch signals the microcomputer when the air conditioner clutch is engaged (Fig. 20–9). The microcomputer uses this signal to adjust the idle speed whenever the air conditioner compressor is engaged. This action is necessary to maintain engine idle speed while the engine is operating under the load of the compressor.

Battery Signal

There are two battery power supply circuits to the microcomputer or ECM. The first is a fused circuit from the battery to the microcomputer (Fig. 20–10). This circuit powers the diagnostic memory of the microcomputer. Moreover, the microcomputer senses the amount of operating voltage provided by the battery via the circuit. If the voltage falls below a predetermined amount, the microcomputer sends an output signal to the idle speed motor to increase engine speed. This action raises the speed of the alternator so that its output will increase.

The second power supply comes from the ignition switch when it is turned on. With the switch on, battery power starts the microcomputer's programmed routine, which sets up its many operating functions. Battery power via the ignition switch also is directed to most of the microcomputer output devices.

Park/Neutral Switch

The *park/neutral switch* is incorporated into the neutral safety switch found on vehicles with automatic

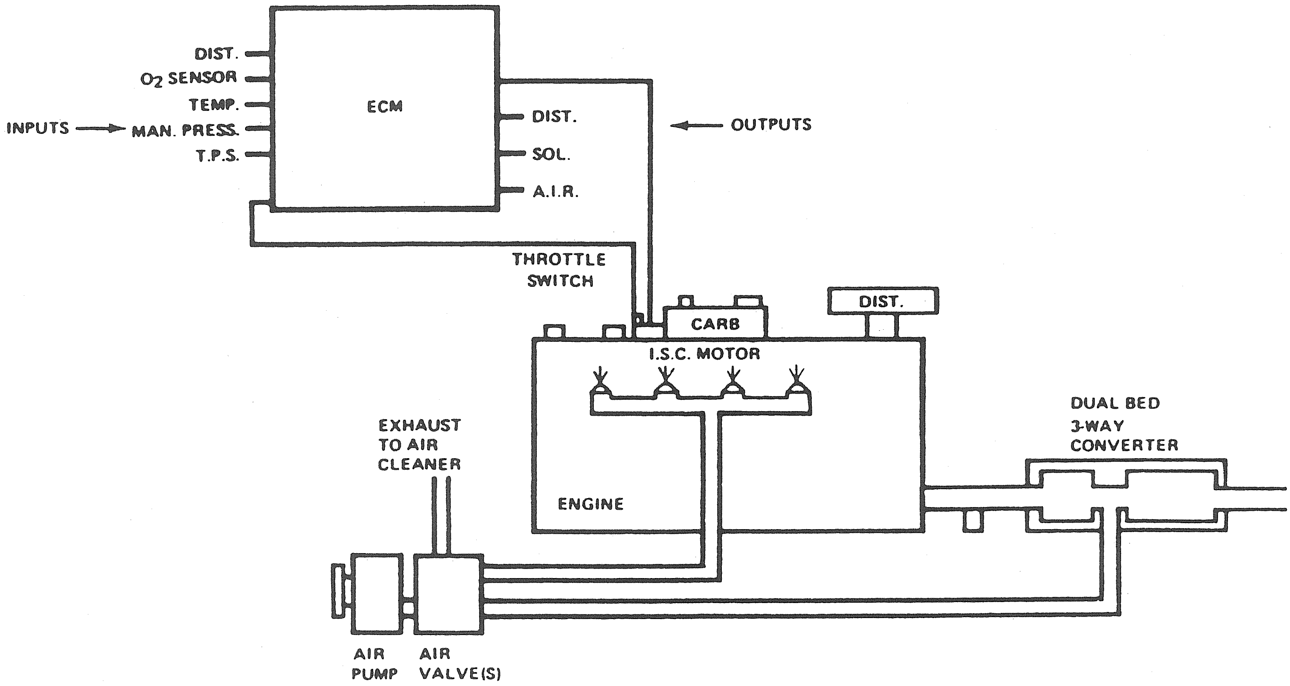


FIGURE 20-8
Throttle switch signal. (Courtesy of General Motors Corp.)

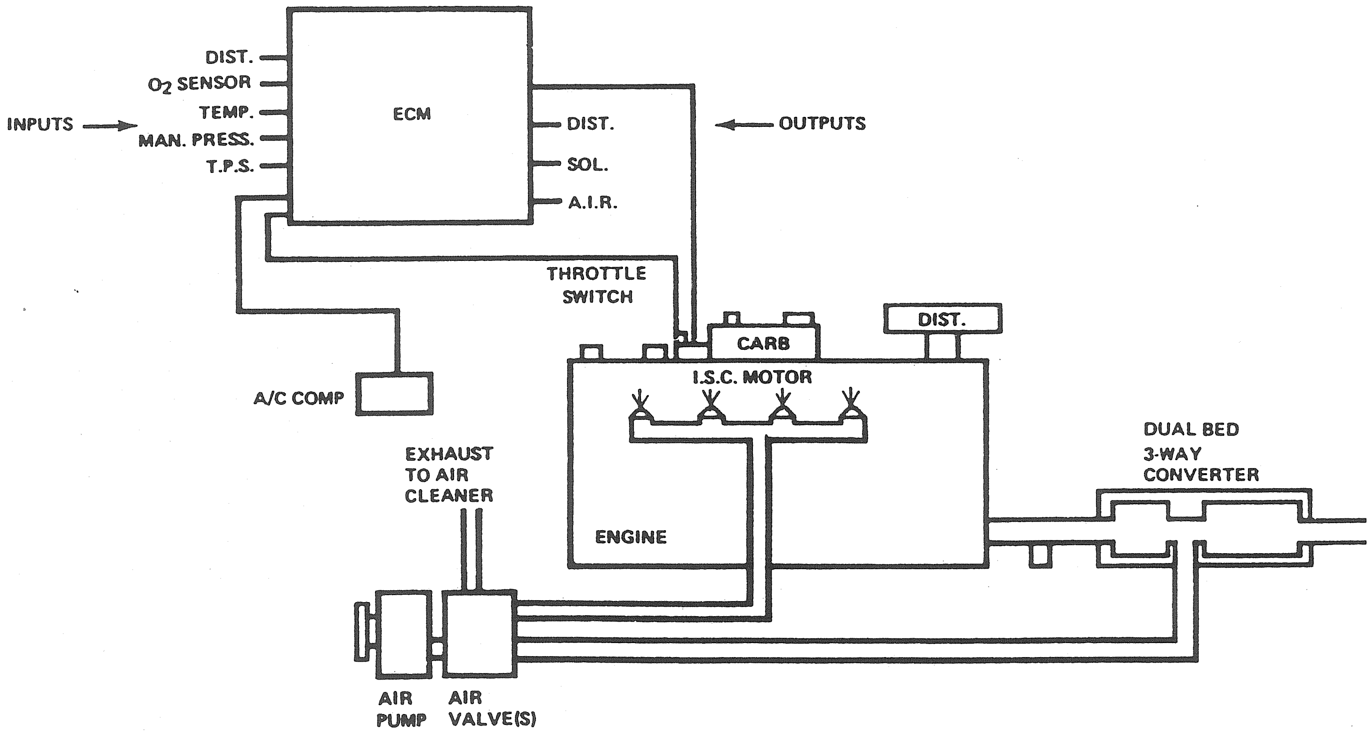


FIGURE 20-9
A/C clutch switch signal. (Courtesy of General Motors Corp.)

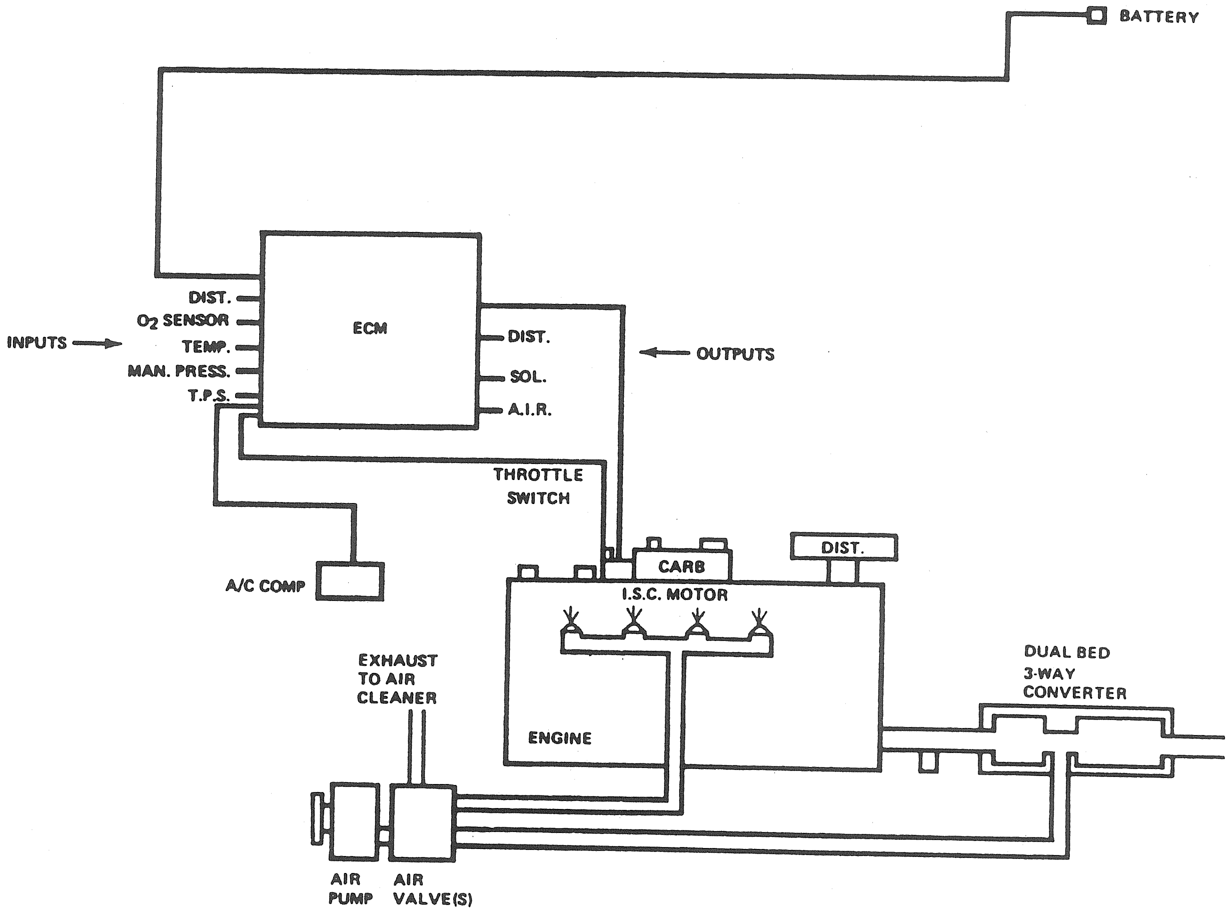


FIGURE 20-10
Battery signal to the ECM. (Courtesy of General Motors Corp.)

transmissions. The park/neutral switch signals the microcomputer whether the transmission is in gear or not (Fig. 20-11). If the transmission is placed in gear, the signal informs the microcomputer of an impending engine load. The microcomputer then directs a signal to the idle speed motor to increase engine speed. This action prevents, for example, uneven engine idle speeds as the transmission selector is moved from neutral to reverse or drive.

Transmission Gear Switches

Most vehicles with the CCC system and automatic transmissions have one or more hydraulically operated switches that thread into the valve body. These second, third, or fourth gear switches are the on/off type that provide the microcomputer with signals indicating what gear the transmission is in. This information is used by the microcomputer to more effectively control torque converter clutch operation and, to some extent, emission control components.

Figure 20-12 illustrates a typical fourth gear switch circuit. In any forward gear ratio but fourth, this switch is closed. This connects microcomputer (ECM) Terminal N to ground via Terminal B. Terminal N is a 12-volt source, which is virtually pulled down to 0 volts when the switch is closed.

When the transmission upshifts to fourth gear, the switch opens. This permits the voltage at Terminal N to reach battery voltage. The increase in voltage signals the microcomputer that the transmission is in fourth gear and that is should apply the torque converter clutch under certain conditions. The vehicle, for instance, must be operating at over 35 mph and the throttle be between 20 percent and 70 percent open.

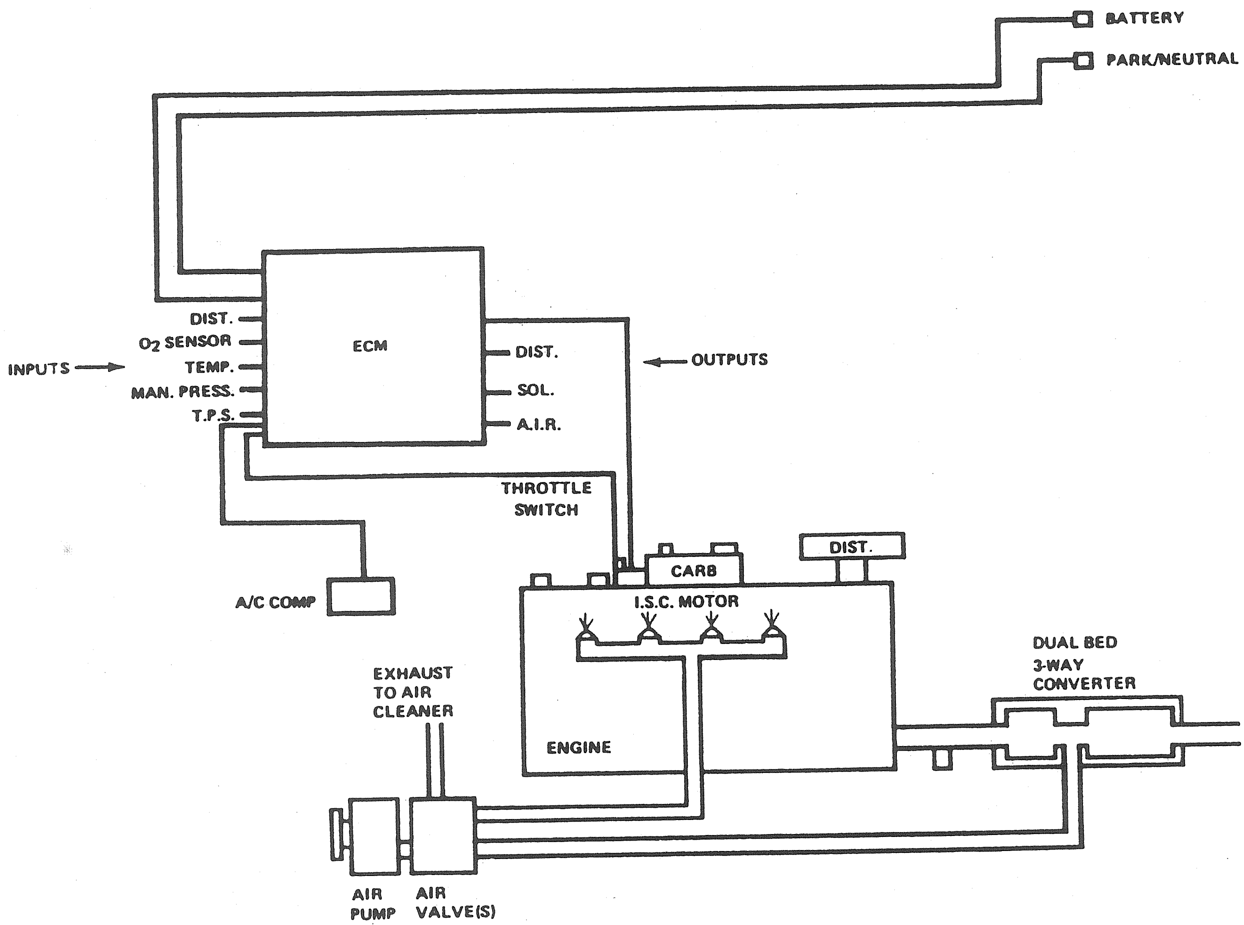


FIGURE 20–11
Park/neutral switch signal. (Courtesy of General Motors Corp.)

20-2 CCC SYSTEM OUTPUTS

The microcomputer for the computer command control (CCC) system provides eight output command signals. These energize the mixture control solenoid, electronic spark timing, idle speed motor, air injection solenoids, EGR solenoid, canister purge solenoid, torque converter clutch, and the EFE relay.

Mixture Control Solenoid

The carburetor used on all CCC system applications has some form of *mixture control solenoid*. This solenoid is an electromechanical device that precisely controls the air/fuel ratio in both the main and idle circuits.

Figure 20–13 illustrates one of the mixture control solenoids in use. This particular device is located within the float bowl of the carburetor where the piston for the power circuit used to be. The assembly consists of the solenoid coil with an air core and a plunger.

The spring-loaded plunger can move up or down within the air core just like a power piston would, but the former can move much more rapidly. An extended bracket on the head of the plunger contacts the metering rods and an idle air-bleed valve. As a result, the plunger movement controls both the metering rods and the air bleed at the same time.

In this way, the solenoid varies the air/fuel ratio based on a command from the microcomputer. When the solenoid is energized by the microcomputer, the solenoid plunger is pulled down by electromagnetism. When this occurs, the metering rods move down into the jets to restrict fuel flow to the main well, and the idle air-bleed valve opens, adding air to the idle circuit. This action provides the engine with a lean mixture of about 18:1 no matter whether the carburetor idle or main circuit is providing the

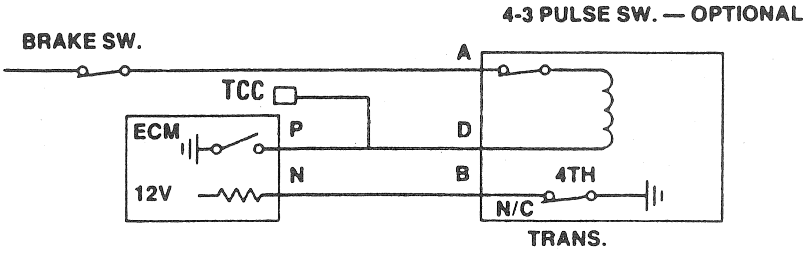


FIGURE 20-12
Fourth gear switch schematic. (Courtesy of General Motors Corp.)

air/fuel ratio.

Whenever the microcomputer de-energizes the solenoid, the plunger moves up due to spring action. When this happens, each of the metering rods also moves upward by the tension of its own spring. This allows more fuel into the main well. At the same time, the plunger extension closes the idle air-bleed valve by means of its contact stem. This increases fuel flow in the idle circuit. Consequently, the de-energized solenoid has the effect of providing a richer air/fuel ratio of about 13:1 to the engine, no matter whether the idle or main circuit is operating.

However, during closed loop operation, the microcomputer regulates the mixture control solenoid's on and off time, so it provides an air/fuel ratio of about 14.7:1. To do this, the microcomputer is programmed to cycle the solenoid on and off ten times per second. Moreover, the microcomputer cannot vary from this ten cycles per second routine except when it is shut down.

However, the microcomputer can vary the duty cycle (solenoid on-time) anywhere from 90 percent to 10 percent (Fig. 20-14). For instance, a lean 90 percent duty cycle means that the solenoid is energized to pull and hold the plunger down for 90 percent of the total cycle time. The solenoid is de-energized and the plunger is therefore up only 10 percent of the time. On the other hand, a rich 10 percent duty cycle means that the solenoid is energized and pulls the plunger down only 10 percent of the total cycle period.

The ignition switch, when turned on, provides battery voltage to the mixture control solenoid through Terminal B (Fig. 20-15). However, the microcomputer energizes the solenoid by providing a ground circuit from Terminal A to 18 and through an output driver transistor.

In other words, the microcomputer duty cycles the solenoid by supplying an output command signal to the transistor base circuit. This turns the transistor on, which completes the solenoid ground circuit through the collector/emitter circuit, as shown in Fig. 20-15.

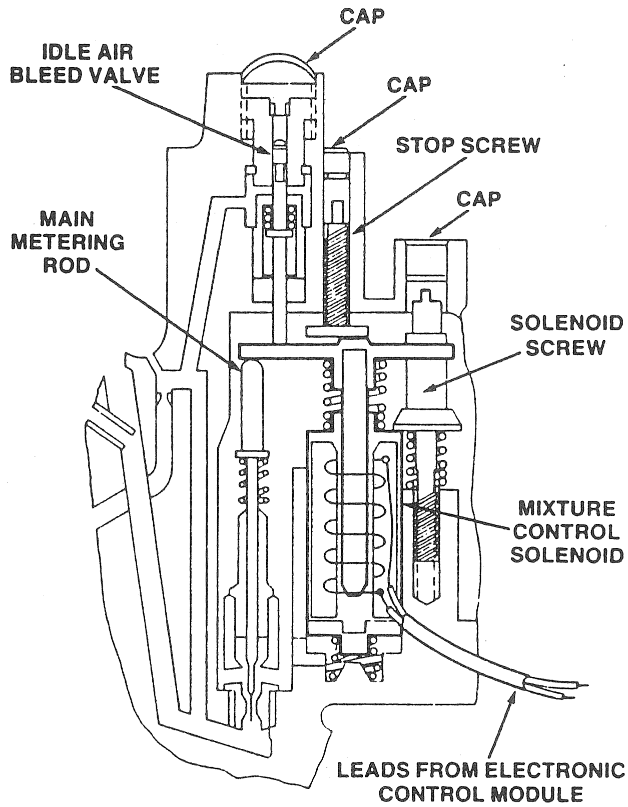


FIGURE 20-13
Typical mixture control solenoid. (Courtesy of General Motors Corp.)

Electronic Spark Timing

Most microcomputers used in the CCC system also provide an *electronic spark timing (EST)* output signal. This eliminates the need for the vacuum as well as the centrifugal advance mechanisms found in the earlier HEI distributors. The reason for the change to electronic control is that is has been found to provide much more exact and reliable control of ignition timing during all phases of engine operation.

To provide electronic spark timing, the HEI ignition module has been modified to operate in con-

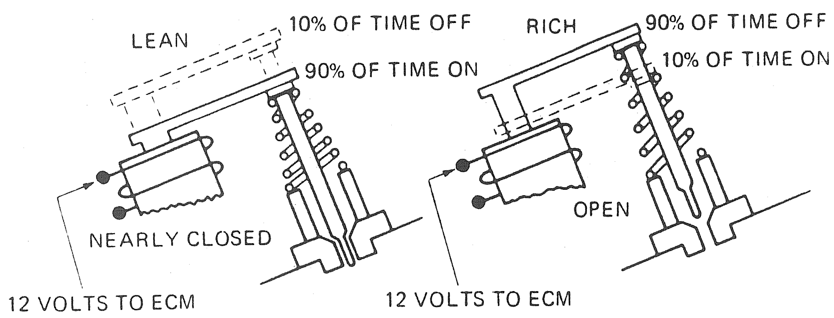


FIGURE 20-14
Lean and rich solenoid duty cycles.

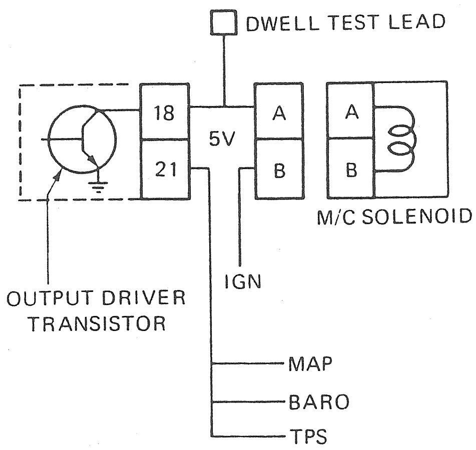


FIGURE 20-15
Mixture control solenoid circuit.

junction with the microcomputer. The HEI electronic spark timing module has seven terminals. Four of these connect the module to the EST electronic circuits within the microcomputer (Fig. 20-16).

The EST circuits are found within the programmable read only memory (PROM) portion of the microcomputer. These provide a basic spark advance curve based on engine speed. However, a number of sensor input signals are used by the microcomputer to modify the PROM data to increase or decrease spark advance to achieve maximum performance with minimum exhaust emissions. The input signals include barometric and manifold pressure, coolant temperature, and engine speed and crankshaft position.

The key to how the microcomputer adjusts ignition timing via the EST signal lies in the solid state circuitry within the HEI module. In Fig. 20-

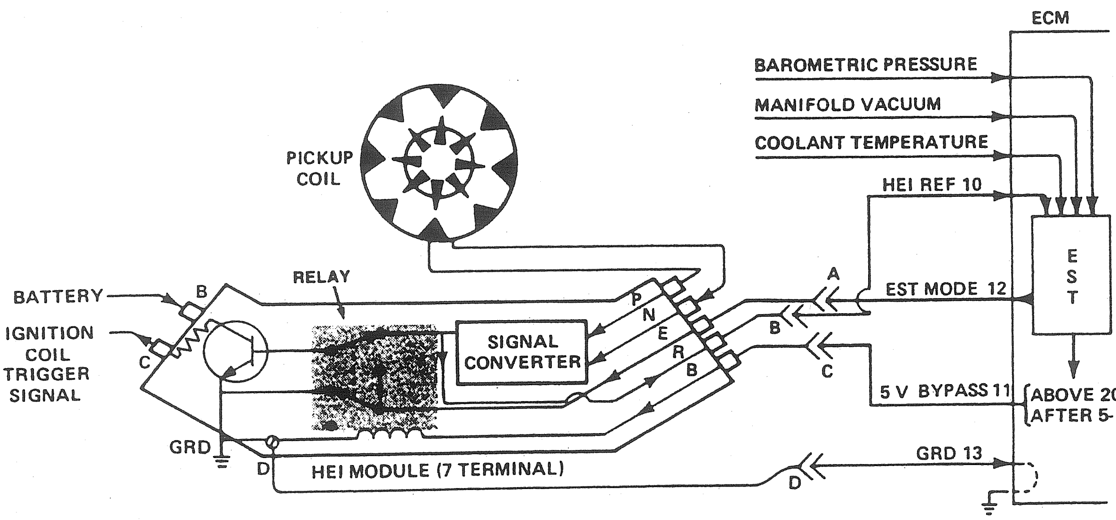


FIGURE 20-16
Electronic spark timing (EST) schematic with engine cranking. (Courtesy of General Motors Corp.)

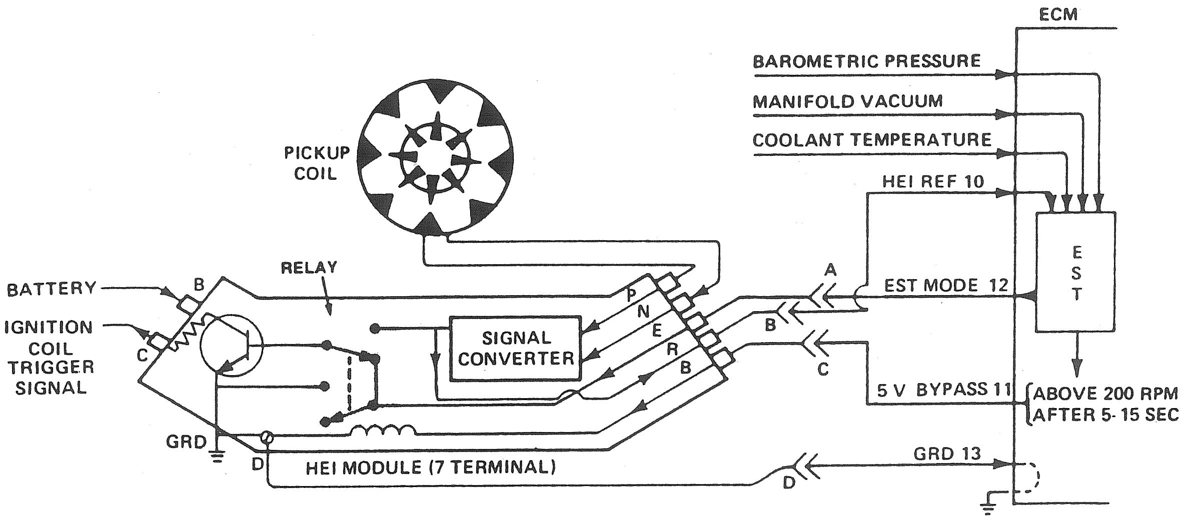


FIGURE 20-17
EST schematic with engine running. (Courtesy of General Motors Corp.)

16, this circuitry is represented by a relay with a double set of contact points. The relay is used for this purpose only to make it easier for you to understand how the EST signal controls the ignition timing.

When the engine is cranking over during a start, the relay is in the de-energized position. This effectively connects the pickup coil within the distributor to the base of the switching transistor. After the pickup coil positive signal has been converted from analog to digital, it turns the transistor on. A zero voltage signal turns the transistor off.

With the transistor turned on, current flows through the primary windings of the ignition coil. When the transistor is off, primary current flow stops, and a high secondary voltage is induced in the secondary coil that produces the arc at the spark plug gap.

This is known as the *module mode* of EST operation. During this period, a small amount of timing advance is programmed into the module itself to promote good engine start-up.

A pickup coil circuit to the transistor has a branch that passes a signal to the microcomputer via Terminal R. This signal is known as the HEI reference (REF) pulse that provides crankshaft position and speed information to the microcomputer. From it and other input signals, the programmed EST circuitry within the PROM develops the EST timing signal. Moreover, the circuitry is capable of varying the time periods when the EST signal passes back to the HEI module through Terminal E. However, during engine cranking, the lower set of contacts are closed, so the EST signal is grounded.

When the microcomputer receives an HEI REF pulse signal of about 200 rpm or more for about 5 to 15 seconds, it considers the engine to be running (Fig. 20-17). It then directs a five-volt signal through the bypass line and Terminal B of the HEI module. This energizes the relay and causes the contacts to move. The upper contact now disconnects the base of the switching transistor from the pickup coil circuit and connects it to the EST signal. The lower contact at the same time disconnects the EST signal from ground.

At this point, the operation of the HEI switching transistor is controlled by the EST signal. This is called the *EST mode* of operation, in which the built-in module timing control is bypassed. The time at which the spark now occurs is determined by when the EST signal occurs, as calculated by the circuitry within the microcomputer.

Idle Speed Control

The idle speed on most CCC engines is controlled by an electric motor that is activated by a microcomputer output signal. The *idle speed control (ISC)* motor mounts on the side of the carburetor and is the reversible type (Fig. 20-18). When activated by the microcomputer, the motor actually changes throttle position (either more open or closed) by acting as a moveable idle stop. As a result, the microcomputer-controlled ISC motor maintains a given idle speed, even when the engine is under a load. In other words, the motor maintains a selected idle speed re-

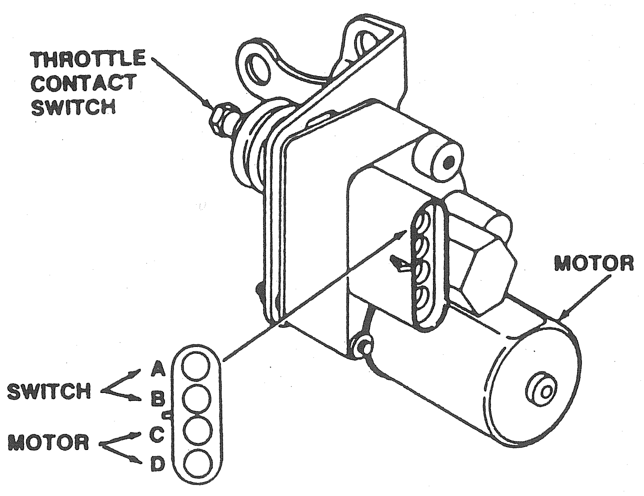


FIGURE 20-18
Idle speed control motor. (Courtesy of General Motors Corp.)

gardless of the load imposed on the engine. The end result is a more accurate way of controlling idle speed to promote driveability and increase fuel economy.

As in the case of EST, the base idle speed is programmed into PROM. However, a number of sensor inputs to the microcomputer will cause it to adjust the base idle to fit given operating conditions. For instance, the temperature sensor signal reflects the temperature of the engine coolant. When the engine is cold, the sensor signal informs the microcomputer that a higher idle speed is necessary. The microcomputer then energizes the ISC motor until the desired idle speed is reached.

However, keep in mind that the carburetor fast idle cam also holds the throttle open when the engine is cold and the choke is applied. Therefore, the ISC motor will only increase idle speed during engine warm-up when the choke is open, allowing the fast idle cam to fall away and the throttle lever to contact the motor plunger; and when the microcomputer is still receiving a cold coolant temperature signal.

The coolant temperature sensor also signals the microcomputer if the engine overheats. It, in turn, will then energize the ISC motor to increase idle speed that helps cool down the engine.

Another important input is the distributor speed signal. The microcomputer uses it to determine if the engine is operating at the correct idle and then either energizes the ISC motor to increase or decrease the speed as necessary.

The microcomputer also receives an input signal if the air conditioning is turned on via the A/C clutch switch. The microcomputer then signals the ISC to provide a wider throttle opening to compensate for the additional load on the engine caused by the operation of the air conditioning compressor.

The battery signal is used by the microcomputer to sense system operating voltage. If the voltage signal falls below a pre-set amount, the microcomputer energizes the ISC motor to extend its plunger, thus increasing engine speed. This increases alternator speed so that its output will go up.

The park/neutral switch signals the microcomputer of an impending transmission gear ratio change, which will affect the engine load and therefore its idle speed. For example, as the transmission is shifted from neutral to reverse, the switch signal allows the microcomputer to anticipate the higher load that is coming and to energize the ISC to raise the idle while the shift is actually being made.

The final input signal to the microcomputer that affects ISC operation comes from the *throttle contact switch* that is built into its actuating plunger. The signal from this switch determines whether the microcomputer should in fact energize the ISC motor or not. For instance, when the throttle lever rests on the switch, it is closed. After receiving this closed signal, the microcomputer will energize the ISC as necessary to regulate idle speed.

When the throttle is open enough so that the lever moves off the switch, it opens. In this case, the open signal causes the microcomputer to energize the ISC so that its plunger extends. It then stops sending any idle speed output signals to the ISC. At this point, the driver is in control of engine speed.

Beginning in 1982, CCC applications with smaller engines were also given an ISC relay. The relay consists of a solid-state, fixed-time delay device. Its purpose is to keep the ISC motor activated in the retract mode for a period of time after the ignition key is turned off. This permits the throttle to completely close every time the engine is turned off in order to prevent dieseling.

AIR Management

As one of its output signals, the microcomputer also manages or controls the flow of air from the air injection reaction (AIR) system. In other words, the microcomputer directs the flow of air coming from the belt-driven air pump into the exhaust ports, the air cleaner, or the center of the three-way catalytic converter.

The air is diverted into the exhaust ports when the engine is below operating temperature for sev-

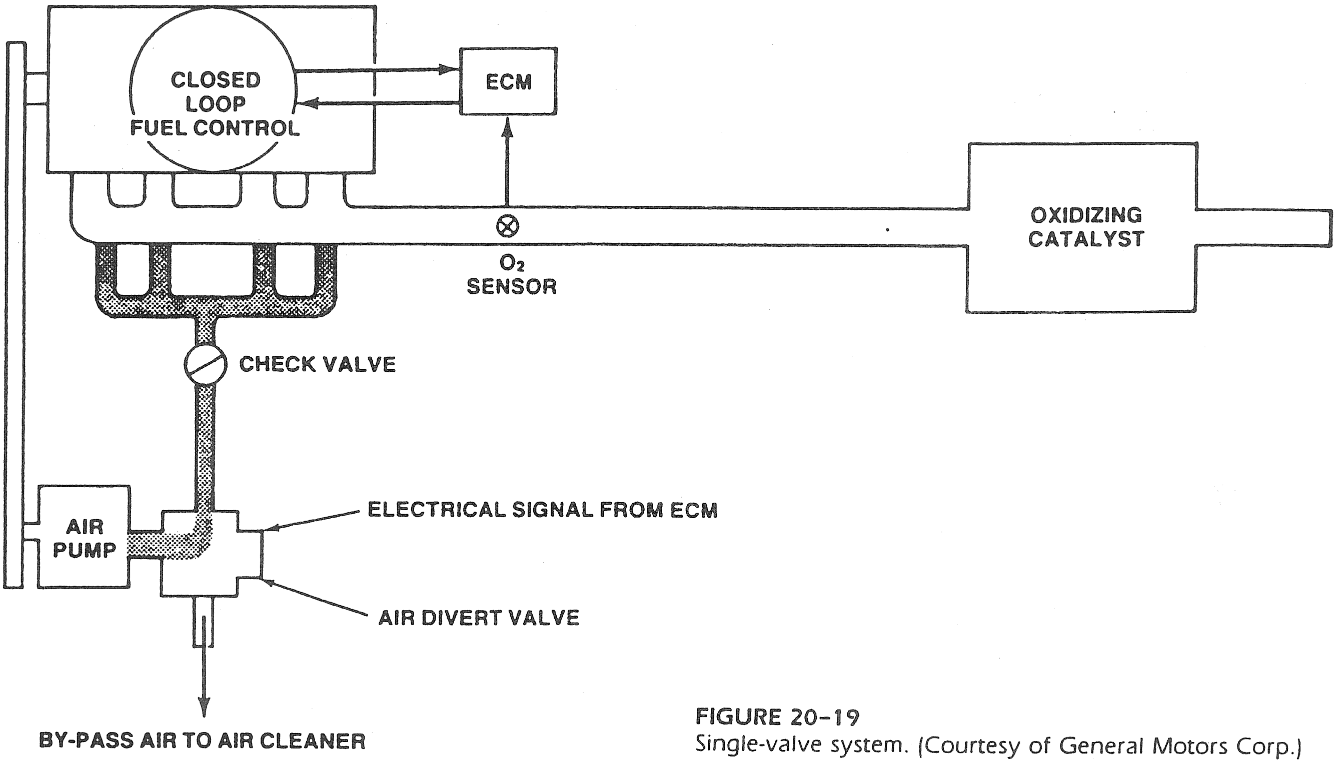


FIGURE 20-19
Single-valve system. (Courtesy of General Motors Corp.)

eral reasons. First, the added air contains oxygen, which helps to continue the burning of hydrocarbons within the manifold area. Second, the additional burning process creates more heat in the exhaust system than it would have normally. This helps to warm up to its operating range not only the oxygen sensor but also the catalytic converter. For the converter to operate properly, it must be hot enough so that a 50 percent conversion efficiency of HC, CO, and NO_x can take place. To do this, the converter catalyst must be between 410°F and 500°F (210°C and 260°C), which is known as its *light-off temperature.*

If large amounts of HC and CO enter the exhaust, a backfire can occur or the converter can be damaged. The damage is due to the rapid rise in temperature as the unit attempts to convert these harmful emissions. Therefore, pump air is diverted by microcomputer command during high engine loads, deceleration (to prevent a backfire), system malfunctions and high engine speeds.

With the engine at normal operating temperature, the microcomputer directs the air into the center of the three-way converter, if the vehicle is so equipped, instead of the exhaust ports. The air assists the rear portion of the converter in oxidizing the HC and CO compounds remaining in the exhaust gases. In addition, the reduction of air in the exhaust ports aids the reducing catalyst in the front portion of the converter in decreasing NO_x levels. Finally, if pump air is not cut off to the exhaust ports when the engine is at normal operating temperature, its oxygen content would cause the oxygen sensor to send a lean signal to the microcomputer. The microcomputer, in turn, would enrich the air/fuel mixture to compensate for the false signal.

When the vehicle has just an oxidizing converter (Fig. 20-19), the management system requires only a single valve. This valve will do one of two things according to the output signal from the microcomputer. First, the valve will direct pump air to the exhaust ports to further oxidize the HC and CO compounds within the exhaust gases. Second, the valve will divert pump air from the exhaust ports to the air cleaner or intake manifold to prevent a backfire on deceleration, protect the catalytic converter, and improve fuel economy.

Vehicles with a three-way converter require an integral unit that incorporates two valves into one assembly (Fig. 20-20). In this system, the integral valve not only serves the same functions as a single-type assembly but also directs air between the two beds of the three-way converter during closed loop operation.

On the various CCC system applications, there are many different valve designs in use. This makes

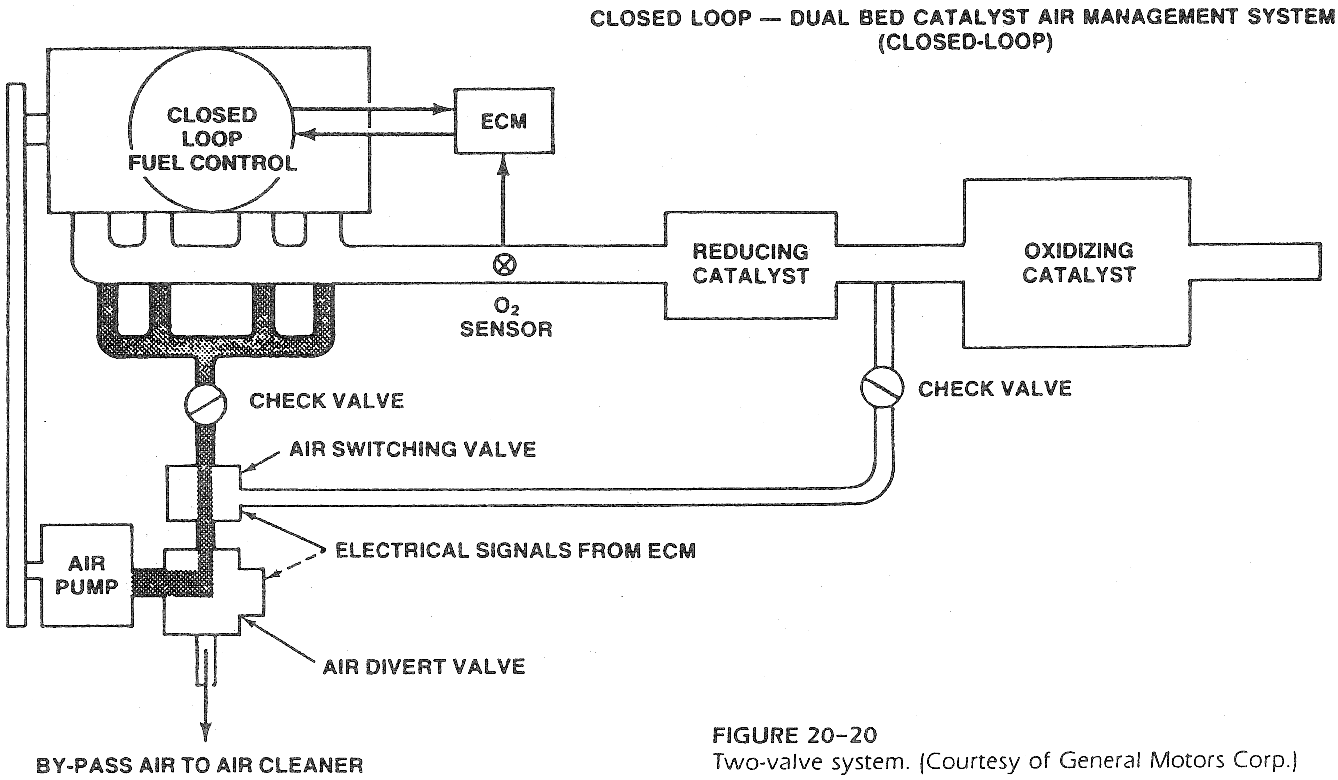


FIGURE 20-20
Two-valve system. (Courtesy of General Motors Corp.)

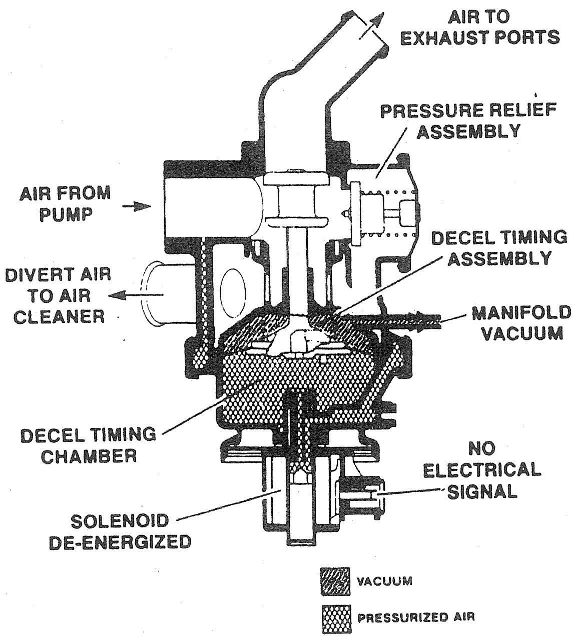


FIGURE 20-21
Electric air control valve. (Courtesy of General Motors Corp.)

a discussion of each individual type impractical in the space confines of this chapter. However, most of the valves are similar in design and operation in that they direct pump air flow by moving an integral valve to open or block a passage.

Figure 20-21, for example, shows an *electric control valve (EAC)* used in the single-valve system. This device combines microcomputer control with the normal function of a vacuum-operated air diverter valve. The EAC bolts to the air pump and consists of a pressure relief valve, diaphragm and double-acting valve, calibrated spring, vacuum tube and chamber, decel timing chamber, and electric solenoid. The spring-loaded relief valve controls system pressure by exhausting excess pump air to the air cleaner.

The diaphragm and double-acting valve mount between two sealed chambers, the manifold vacuum and decel timing. The calibrated spring holds the diaphragm and double-acting valve in the down or normal operating position.

The vacuum chamber has a signal tube that connects via a hose to the intake manifold. Therefore, with the engine operating, vacuum acts on the upper side of the diaphragm. Normally, the vacuum would move the diaphragm and the valve to the up or divert position, further compressing the calibrated spring. However, the normal vacuum signal is bled off through the *decel timing assembly* that is located in the metering valve stem. Consequently, the spring maintains the valve in the down position during normal engine operation.

The *decel timing chamber* is pressurized during

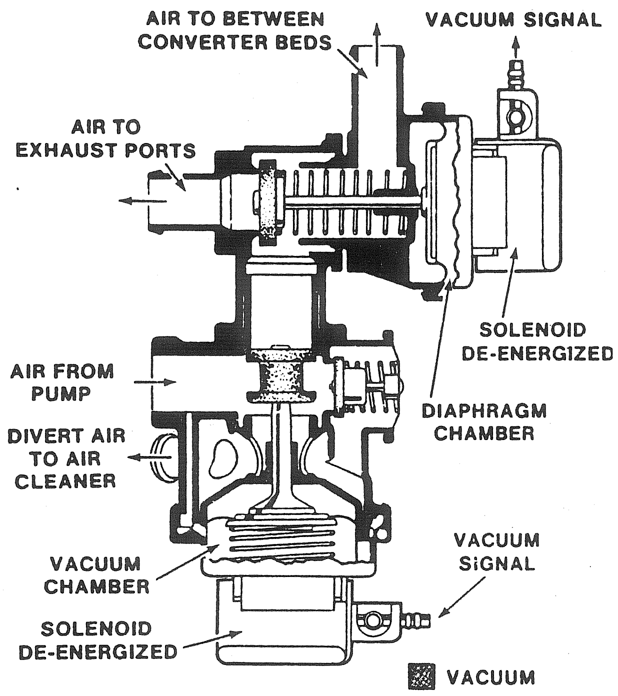


FIGURE 20–22
Electric divert/electric switching (EDES) valve. (Courtesy of General Motors Corp.)

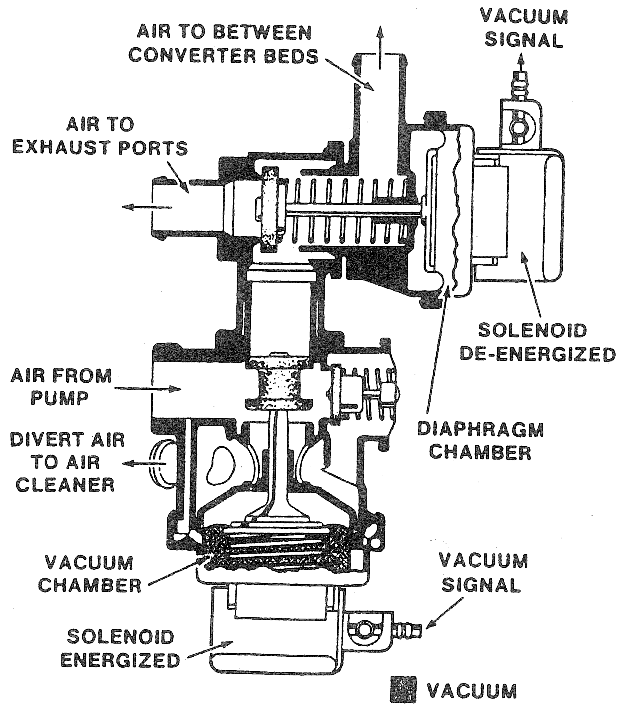


FIGURE 20–23
EDES valve diverting air to the air cleaner. (Courtesy of General Motors Corp.)

engine deceleration by air from the pump. The air places sufficient pressure on the diaphragm to overcome spring tension. As a result, the diaphragm and valve move upward, closing off the air flow to the exhaust ports. In this situation, pump air now diverts to the air cleaner.

The *electric solenoid* controls the air flow from the pump to the decel chamber. When the microcomputer de-energizes the solenoid, pump air meters into the chamber, causing the EAC valve to divert pump air to the air cleaner.

Anytime the microcomputer energizes the solenoid, pump air is cut off from the decel chamber. The EAC can then act like a standard diverter valve and direct pump air to the exhaust ports. The microcomputer energizes the solenoid by completing its ground circuit via an output driver transistor.

One of the typical integral units used on the CCC two-valve system is the *electric divert/electric air switching (EDES)* assembly (Fig. 20–22). This unit consists of a diverter valve and solenoid, pressure relief valve, and air switching valve and solenoid.

During normal operation, the microcomputer energizes the diverter solenoid. The solenoid now opens to permit engine vacuum to enter the lower vacuum chamber and act on the bottom of the diverter diaphragm. The diaphragm moves down against spring tension and seats the lower portion of the double-acting valve. At this time, pump air can pass through the channel to the air switching valve.

Whenever the microcomputer decides an air divert is necessary, it de-energizes the solenoid. The solenoid valve now prevents engine vacuum from acting on the lower chamber. Under this condition, spring tension pushes the diaphragm and its double-acting valve up, causing the air to divert to the air cleaner (Fig. 20–23).

At wide-open throttle, there is not enough engine vacuum available to overcome spring tension. Therefore, the double-acting valve also moves to its up position, so air is diverted to the air cleaner.

The upper portion of the combination valve contains the air switching assembly (Fig. 20–24). This assembly consists of a spring-loaded diaphragm, double-acting valve, valve chamber, and a solenoid.

When the microcomputer energizes this solenoid, it permits engine vacuum to act on the chamber of the diaphragm. The vacuum acting on the diaphragm itself overcomes spring tension, and the attached valve moves to the position shown in Fig. 20–24. Pump air now flows to the exhaust ports to

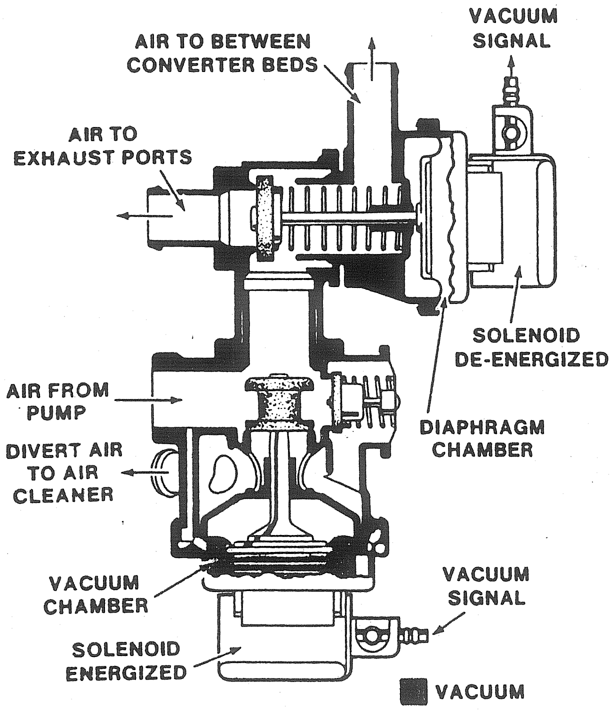


FIGURE 20–24
EDES valve directing air to the exhaust ports. (Courtesy of General Motors Corp.)

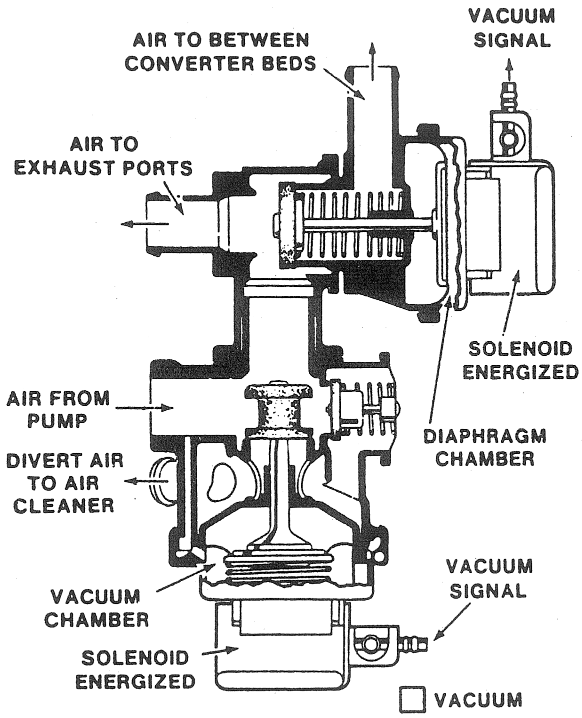


FIGURE 20–25
EDES valve directing air to the converter. (Courtesy of General Motors Corp.)

increase oxidation of the HC and CO compounds.

If the microcomputer de-energizes the solenoid, its integral valve cuts the vacuum off to the diaphragm chamber and vents it to the atmosphere (Fig. 20–25). The spring now moves the diaphragm and its attached valve to the position shown, and pump air flows between the converter beds.

EGR Control

The EGR system is also under the control of a CCC microcomputer output signal. Because of this, the recirculation of exhaust gas is precisely monitored in order to reduce NO_x emissions and detonation while maintaining good driveability. It is a well-known fact that combustion chamber temperatures of about 2500°F result in the formation of NO_x emissions. By recirculating a given amount of exhaust gases, the EGR system can reduce this temperature as much as 500°F. This then reduces the formation of NO_x when the engine is operating at normal coolant temperature.

With the need for increased fuel economy and driveability, the ignition timing has been advanced to a point where detonation becomes a common problem. The controlled recirculation of exhaust gases reduces this tendency by reducing high combustion chamber temperatures, which are a major cause of detonation.

However, the overuse of EGR can create driveability problems. For this reason, the microcomputer will eliminate EGR action during engine startup and warm-up, engine idle, and wide-open throttle operation.

The microcomputer, using sensor inputs that monitor coolant temperature, engine speed, and load, controls the operation of the EGR system by means of one or more electrical solenoid vacuum valves. The number and function of the solenoids depend on the engine and model year application.

Figure 20–26 illustrates the use of a single solenoid EGR system. This solenoid operates a bleed orifice, and the assembly controls the venting of the ported EGR valve signal. For instance, when the normally closed solenoid is energized by the microcomputer, the ported signal vents off to the atmosphere via the open bleed orifice. With the absence of the ported vacuum signal, the EGR valve cannot open to recirculate any exhaust gas.

There are two EGR system designs that utilize more than one solenoid. In the first system (Fig. 20–27), solenoid A controls the carburetor ported vacuum signal to the EGR valve. When this normally open solenoid is energized by the microcomputer,

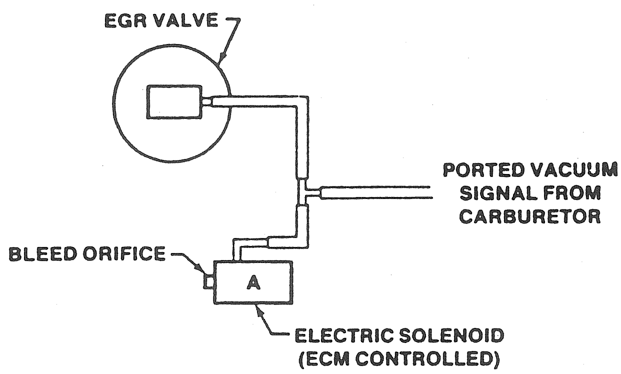


FIGURE 20-26
EGR system with one solenoid. (Courtesy of General Motors Corp.)

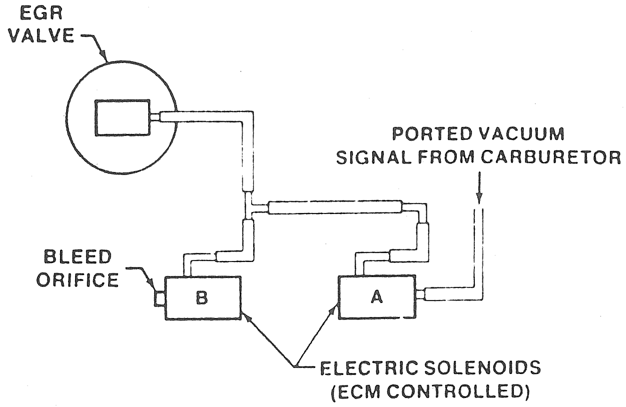


FIGURE 20-27
EGR system using two solenoids. (Courtesy of General Motors Corp.)

the vacuum signal is cut off to the EGR valve. Solenoid B acts as a vent for the EGR ported signal.

There is only one real difference between this and the single solenoid system just described. That is, the microcomputer can precisely control the amount of EGR valve opening by regulating both the amount of vacuum applied and what is trapped within the system.

The other system design also uses two solenoids, but these have a different function (Fig. 20-28). In the first place, the system uses a constant vacuum from an auxiliary pump in place of a ported signal. To convert this auxiliary vacuum to a variable signal, the microcomputer duty cycles solenoid A (i.e., turns it on and off with the on-time variable). By doing so, the microcomputer creates a ported-type system from the auxiliary source. The microcomputer duty cycles solenoid A based on engine speed signals during closed loop operation.

Solenoid B is also just an electrically controlled vacuum valve that is either open or closed. The microcomputer energizes or de-energizes this solenoid based on signals relating to coolant temperature and engine load.

With this arrangement, both solenoids control the operation of the EGR valve. Solenoid A is used to develop a variable signal in proportion to engine speed from a constant vacuum source. Solenoid B will either permit or cut off this variable signal to the EGR valve.

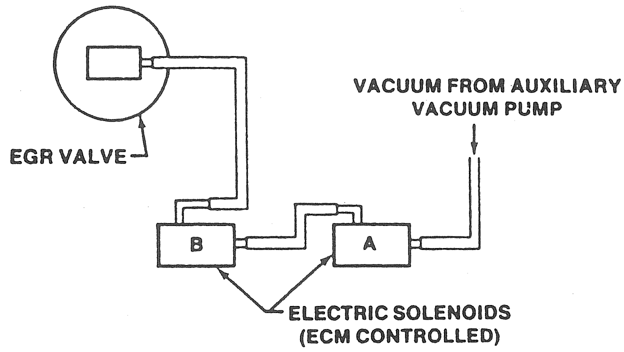


FIGURE 20-28
EGR system using two solenoids and an auxiliary vacuum source. (Courtesy of General Motors Corp.)

Canister Purge Control

On many CCC applications, the microcomputer output signal operates a *canister purge control solenoid* (Fig. 20-29). This unit controls the ported vacuum to the purge valve on the carbon canister. When purging is desirable, the microcomputer de-energizes the normally open solenoid valve. With the valve now in the open position, vacuum is applied to the purge valve. As a result, fuel vapors are then drawn into the intake manifold to mix with the air/fuel mixture before entering the combustion chambers for burning.

When the microcomputer signal energizes the solenoid by supplying a ground circuit, the normally open valve closes. This cuts off the ported vacuum signal to the purge valve, and fuel vapors no longer flow into the manifold. The microcomputer will energize the solenoid and provide a no-purge when the engine run time is less than specified, when the coolant temperature is below a given value, when engine speed is less than a specified value, or when the TP sensor output signal is below a specified value.

Control of the Torque Converter Clutch

The microcomputer of the CCC system provides an output signal that controls the operation of the *torque converter clutch (TCC)*. The clutch itself im-

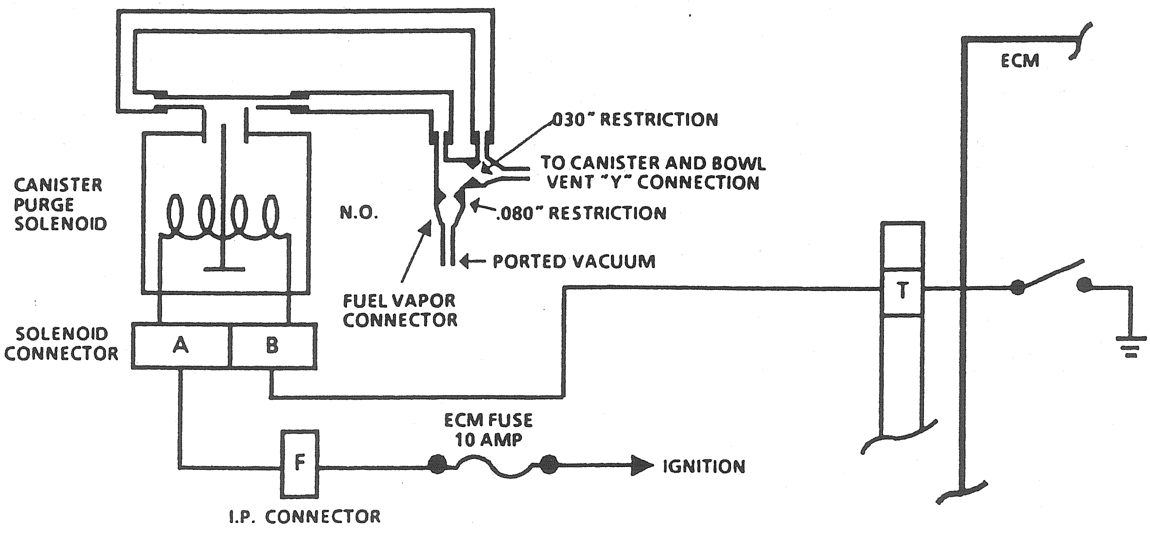


FIGURE 20-29
Schematic of a canister purge solenoid circuit. (Courtesy of General Motors Corp.)

proves fuel economy by eliminating the slippage within the standard torque converter that exists even at vehicle cruising speeds. In other words, the TCC offers the fuel economy of a manual transmission with the convenience of an automatic transmission. In addition, by locking the converter up, there is less heat generated within the transmission fluid.

The microcomputer controls TCC operation through a solenoid located inside the automatic transmission (Fig. 20-30). When the microcomputer energizes the solenoid, the torque converter clutch is applied. This results in a straight-through mechanical coupling from the engine to the transmission. With the solenoid de-energized, the TCC releases, which permits conventional torque converter operation.

The solenoid receives battery power from the ignition switch via a fuse, brake switch, and the transmission's third gear apply switch. The microcomputer energizes the solenoid by providing a ground circuit through Terminal A7 and an output switching transistor.

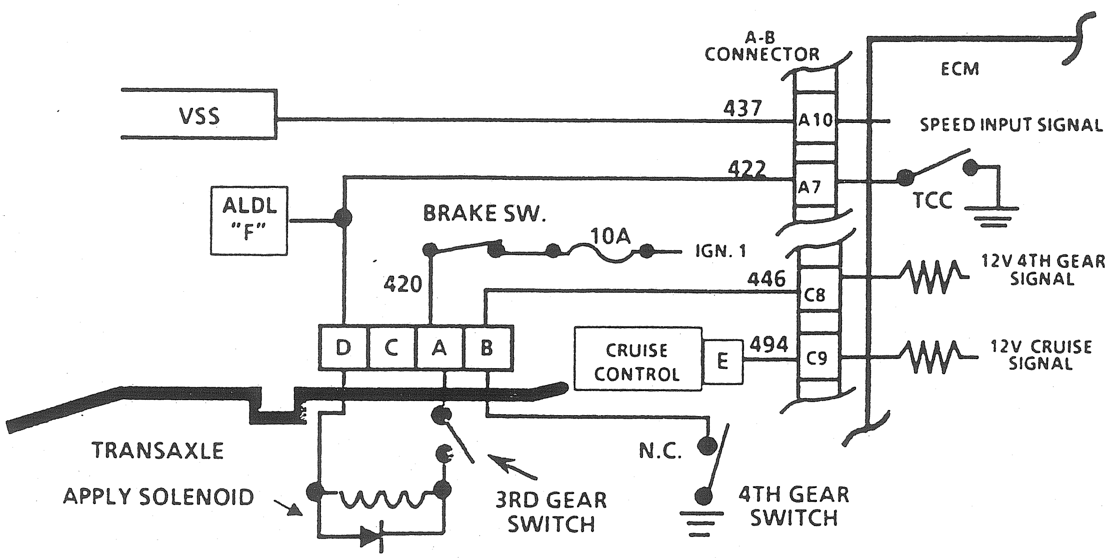


FIGURE 20-30
Torque converter clutch (TCC) circuit schematic. (Courtesy of General Motors Corp.)

The microcomputer uses the following sensor input signals to determine when to energize the TCC solenoid:

- Vehicle speed sensor. This signal must indicate that the vehicle is above a given speed before the clutch can be applied.
- Coolant temperature sensor. This signal must indicate that the engine has reached a specified coolant temperature before the clutch can be applied.
- Throttle position switch. After the clutch is applied, the microcomputer uses the TP sensor signal to de-energize the solenoid when the engine is accelerating or decelerating the vehicle at a certain rate. Otherwise, an unchanging TP sensor signal, which indicates a steady speed, is used to determine when to energize the solenoid.
- Fourth gear switch. The 440-T4 transmission uses this switch to provide input signals to determine TCC engage and disengage points. For example, the switch is open in fourth gear to permit a full-time TCC application. The switch momentarily disengages during downshift from fourth to third gear as the switch closes.

Even when the input signals are correct and the microcomputer provides a ground circuit for the solenoid, other conditions have to be met before it can energize. The internal transmission fluid pressure must be correct. The brake pedal must be released, which closes the brake switch. In addition, the transmission must be in third gear, which closes the third gear switch. The switch also remains closed in fourth gear but opens in second to permit a disengagement of the TCC during a downshift from third to second gear.

EFE Control

The last output signal to be discussed in the CCC microcomputer controls the operation of the *early fuel evaporation (EFE) system.*

The purpose of this system is to apply heat to the intake manifold area beneath the carburetor, which assists in evaporating the fuel in order to keep it in a vapor state.

One of two different types of EFE systems are used on various CCC applications, the exhaust heat and the electric grid. The *exhaust heat system* consists of an EFE power actuator, thermostatic bimetallic valve, one-way check valve, and solenoid. The *power actuator* (Fig. 20–31) is built with a housing that contains a vacuum diaphragm. The diaphragm has an attached actuator rod that operates the valve assembly. This unit regulates the flow of exhaust gases either through the intake manifold crossover passage or into the exhaust pipe.

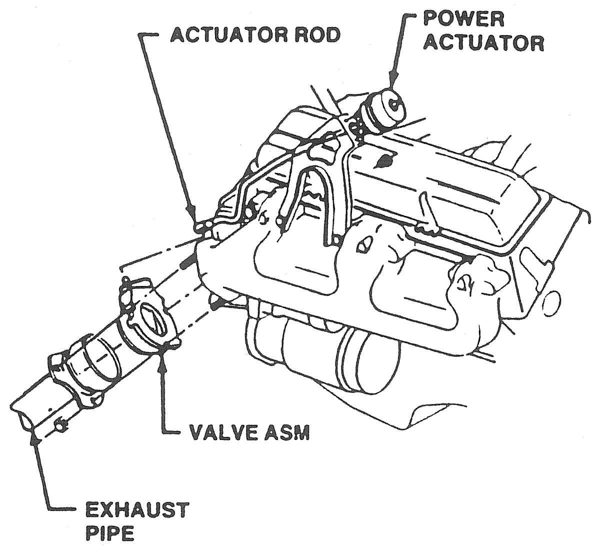


FIGURE 20–31
EFE power actuator. (Courtesy of General Motors Corp.)

There are two valves used on this system, a thermostatic and a one-way check (Fig. 20–32). The *thermostatic valve* is nothing more than a vacuum switch controlled by temperature. It controls the vacuum to the EFE power actuator based on engine compartment temperature. The *one-way check valve* fits into the vacuum signal circuit between the carburetor, solenoid, and the thermovacuum switch. Its function is to prevent pulsing of the vacuum signal during cold operating conditions, which create a clicking noise in the engine.

To provide microcomputer control of the system, a solenoid-operated vacuum valve is installed between the check valve and thermoswitch. This solenoid is energized by the microcomputer by providing it with a ground circuit. The microcomputer energizes and de-energizes the solenoid based on sensor input signals. The solenoid will then permit or totally shut off the vacuum to the actuator based on sensor data, rather than just depending on the action of the vacuum switch. Lastly, a calibrated air bleed in the circuit eliminates any trapped vacuum in the actuator circuit when the solenoid closes and blocks the signal.

The other EFE system uses an *electric heater grid* in place of the actuator and valve assembly. The

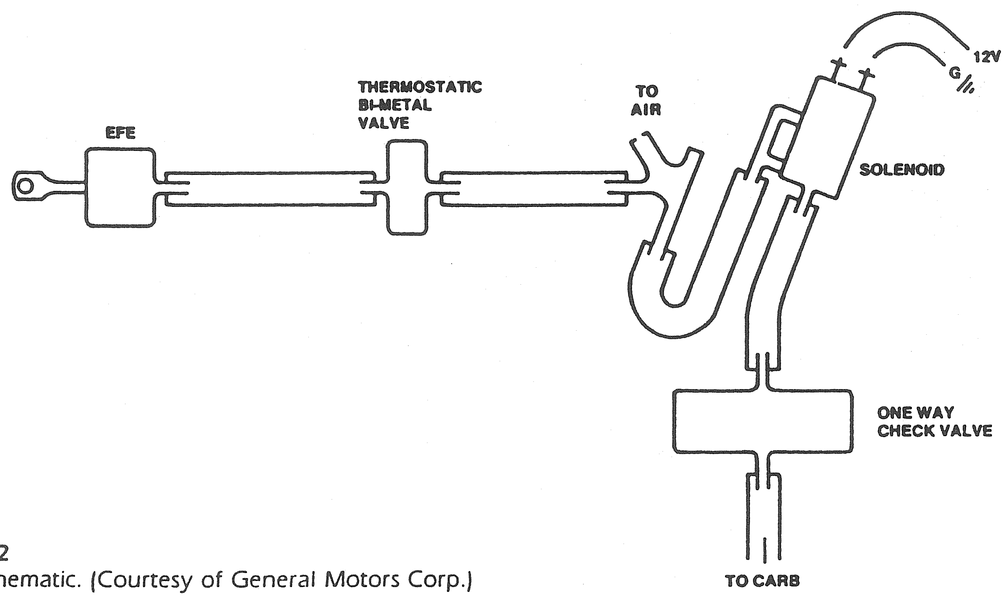


FIGURE 20-32
EFE system schematic. (Courtesy of General Motors Corp.)

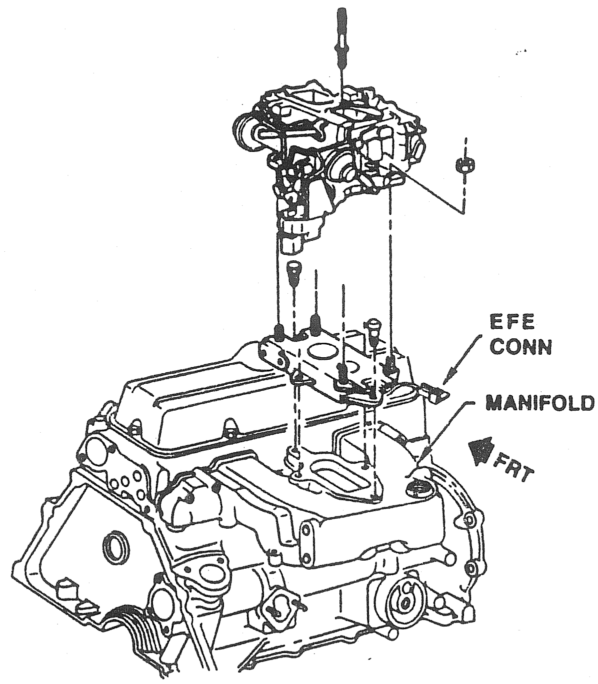


FIGURE 20-33
EFE electric heater grid. (Courtesy of General Motors Corp.)

ceramic heater grid is located under the primary bore of the carburetor as part of the insulator gasket (Fig. 20-33). When energized, the grid heats the incoming air/fuel mixture for improved vaporation.

The microcomputer actually controls grid operation by means of an EFE relay (Fig. 20-34). Within the relay, a set of normally open contacts are connected between the ignition circuit at Terminal A and the EFE heater at E. The relay coil circuit is between the ignition circuit at Terminal C and a microcomputer circuit at Terminal B.

When the engine is cold, the microcomputer provides a ground circuit for the relay coil via Terminal B. As a result, the relay coil energizes, and it causes the contacts to close. With the contacts closed, current flows through the heater grid.

Whenever the engine reaches a given operating temperature, the microcomputer breaks the ground circuit for the relay coil. With the coil de-energized, the contacts open, and the circuit is broken to the EFE heater grid.

20-3 CCC MICROCOMPUTER AND SYSTEM OPERATION

The microcomputer for the CCC system is known as the *electronic control module (ECM)*. It is located in the passenger compartment, usually near the glove compartment or behind the right kick panel (Fig. 20-35). The ECM is a very small, solid-state unit that monitors and controls all the functions of the CCC system. To do this, the ECM acts as a vast number of on and off switches that can either send a voltage signal to a circuit or, more usually, connect a circuit to ground at a precise time. In addition, the ECM can make calculations very quickly (around 250,000 per minute) and can then regulate the operation of a number of engine and emission control systems at the same time. Finally, the ECM has the ability to diagnose itself as well as other CCC system components.

ECM Design

The ECM consists of a microprocessor and a number of storage devices called memories (Fig. 20-36). The *microprocessor* is the brain of the ECM. In other words, it receives input signals from all the sensors, does the calculations, makes the decisions, and provides the output commands to regulate the air/fuel ratio, spark timing, idle speed, and the operation of the various pieces of emission control equipment.

Another very important output command function of the ECM is to provide for system diagnostics via the CHECK ENGINE light and the *assembly line communication link (ALCL)*. The CHECK ENGINE light has two functions. First, when it comes on, it informs the driver that there is a malfunction within the CCC system. Second, the technician can use the light for reading trouble codes stored in memory.

The ALCL connector is located under the dashboard and provides the technician access to the built-in diagnostic system within the ECM. For example, by grounding the trouble code test lead terminal on the connector, the CHECK ENGINE light will flash a trouble code, indicating a problem area.

By connecting a scanner tool like the Monitor 2000 to the ALCL connector, the unit, depending on its design, can access all or part of the data stream to and from the ECM. In other words, the scanner tool will display such factors as engine rpm; loop status, either open or closed; coolant temperature in degrees; TPS voltage reading; oxygen sensor voltage reading; battery voltage; M/C solenoid dwell reading; MAP sensor voltage reading; and BARO sensor voltage reading. The scanner tool will also show whether the following components are turned on or off: diverter solenoid, air switching solenoid, ISC motor status, nose switch position, EFE relay, torque converter, and canister purge solenoid.

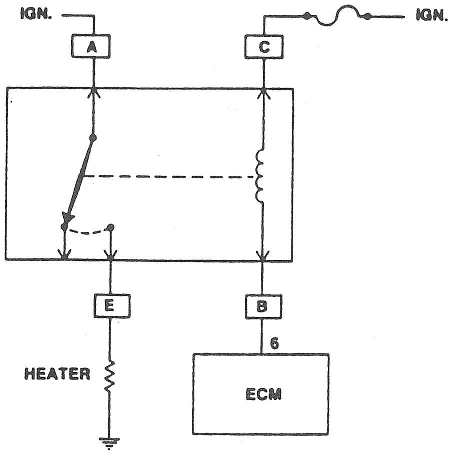


FIGURE 20-34
EFE relay schematic. (Courtesy of General Motors Corp.)

But the microprocessor cannot store information. Therefore, it requires a number of memories that provide the microprocessor with programmed data. The three memories basic to the ECM are the

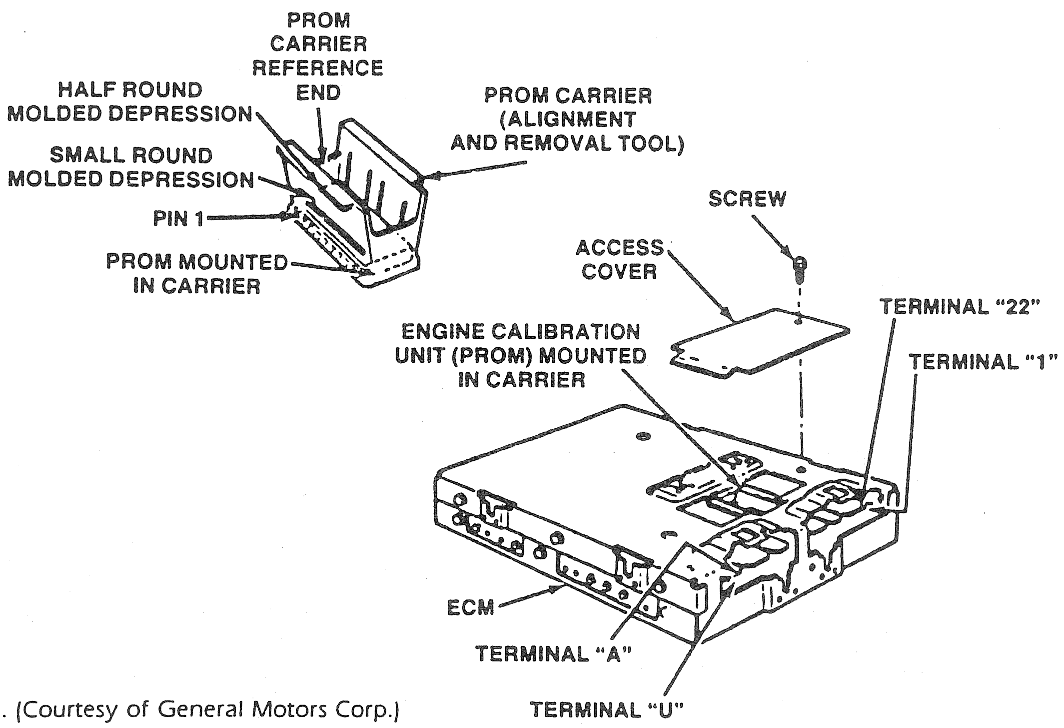


FIGURE 20-35
ECM and PROM. (Courtesy of General Motors Corp.)

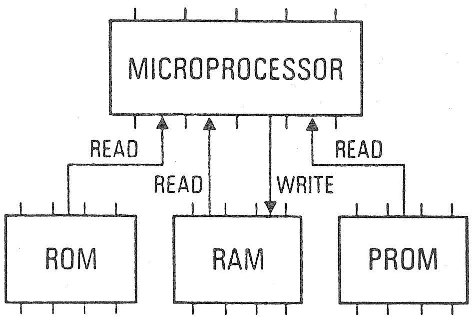


FIGURE 20-36
ECM microprocessor and memories. (Courtesy of General Motors Corp.)

read only, programmable read only, and random access.

ROM. The *read only memory (ROM)* contains programmed information that can be read only by the ECM. In other words, ROM provides permanent data storage. When the ECM is built, the programs that control the microprocessor are stored in ROM in the form of voltage and time values. The microprocessor can read this data from ROM, but it cannot write new information into it.

If battery voltage is removed from the ECM, ROM programmed information will not be lost. For this reason, this type of memory system is called *nonvolatile*.

PROM. The *programmable read only memory (PROM)* also contains factory-programmed data in voltage and time values. However, these data reflect the characteristics that can vary with each vehicle model. The program includes engine calibration information along with data on transmission type, vehicle weight, and rear-axle ratio application. The PROM can be removed from the ECM and does not lose any stored information when battery power is removed from the ECM.

RAM. The *random access memory (RAM)* can be written into and read from (see Fig. 20-36). Because it can be written into, the RAM is used for temporary storage. For example, the microprocessor receives a sensor input signal that it needs to make a number of different decisions. It will write the signal into RAM memory and then read it out each time it is needed. In other words, the RAM is like a scratch pad for the microprocessor. It writes down all input sensor data and the results of calculations. Later, the microprocessor scans both the RAM and PROM memories and then decides on what needs to be done with the information.

There are two kinds of RAM memories: nonvolatile and volatile. A nonvolatile RAM holds its information even if power is removed. A *volatile RAM* will be erased when power is removed. A *keep-alive RAM* is volatile memory that is connected directly to the vehicle battery. In this way, the RAM still receives power when the ignition switch is off. However, if the battery goes dead or its cables are removed, the keep-alive RAM loses its information.

The most important function of the keep-alive RAM is the storing of fault codes. If, for instance, an open circuit occurs during normal operation of the system, a fault code will be stored in the keep-alive RAM. This code can be retrieved at a later time by the technician to assist in locating the cause of the problem. This feature is especially useful because it enables the microprocessor to report a fault that occurred recently but is no longer present, as well as those that are still present. The technician can access fault codes using either the CHECK ENGINE light or a scanner tool.

Lastly, the ECM requires accurate voltage signals sent to it from the sensors if accurate decisions are going to be made. If battery voltage is used for this purpose, then load on the electrical system and changes in engine speed would raise and lower the sensor signal strength. This would give a false input signal to the microprocessor. To avoid this, the ECM directs a constant five-volt reference voltage to such sensors as the MAP, BARO, VACUUM, and TP.

ECM and System Operation

The ECM operates the CCC system using five modes, including the shutdown, start-up, open loop, closed loop, and enrichment.

The ECM enters the *shutdown mode* any time the engine speed reference pulses indicate under 200 rpm or when battery signal voltage is less than nine volts. During this mode, there will be no power supplied to the M/C solenoid by the ignition switch if it is in the off position, nor will the ECM provide a ground circuit for it. As a result, the M/C solenoid will create a full, rich operating condition during shutdown.

When the engine is started hot or cold, the ECM operates in the *start-up mode*, which overrides the remaining three modes. In this situation, the microprocessor duty cycles the M/C solenoid with a rich command signal for a short time after engine start-up. The duration of the rich command depends

on engine temperature, as measured by the coolant sensor. If the engine is hot when started, for instance, the rich signal will be of a shorter duration than if it is started cold.

The *open loop mode* occurs during the engine warm-up period when both engine coolant and oxygen sensor temperatures are low. During this mode, the ECM controls the air/fuel ratio using information stored in ROM and input from the coolant temperature, throttle position, MAP, BARO, and engine speed sensors. As the engine coolant temperature comes up, the ECM leans out of the air/fuel ratio.

In open loop, the ECM will provide system diagnostics, control engine speed and spark timing, and attempt to adjust the air/fuel ratio based on the fixed program stored in ROM and the sensor input signals. However, if the air/fuel ratio is not correct due to problems such as a carburetor malfunction or vacuum leak, the ECM will not recognize or attempt to correct the mixture. In other words, in open loop, the ECM can only do what it is programmed to do. Therefore, the engine will not perform properly until the problem components are repaired.

Before the ECM can enter the *closed loop mode*, three conditions must be met: (1) the engine coolant temperature must reach about 150°F (65°C), (2) the oxygen sensor temperature must be at least 600°F (315°C) in order to generate an accurate working signal to the ECM, and (3) a predetermined time must have elapsed following engine start-up. This time is programmed into PROM and can vary from a few seconds to as much as several minutes on the different engine configurations.

The ECM will drop out of closed loop if the engine is operated near or at wide-open throttle, if the oxygen sensor cools down due to prolonged idle, or if certain system failures occur. During its closed loop mode of operation, the ECM—via its output signals—will control the operation of the following components (Fig. 20-37): mixture control solenoid, electronic spark timing, idle speed motor, air management solenoids, EGR solenoid, torque converter clutch solenoid, air conditioning clutch, EFE solenoid or relay, CHECK ENGINE light, and canister purge solenoid.

20-4 CCC-TBI SYSTEM

In 1982, General Motors introduced *throttle body injection (TBI)*, also called *electronic fuel injection (EFI)*, for use with some CCC system components on some vehicle models. However, TBI did not replace the use of carburetors on a number of other CCC applications.

TBI Advantages

There are a number of advantages to the use of TBI over conventional carburetion. First, although carburetor designs have become refined in recent years, even the addition of electronic feedback systems can only do so much to help the unit maintain the proper air/fuel ratio to match the changing engine operating conditions.

Second, the cost of adding additional circuits and assist devices to carburetors, in order for them to provide the proper air/fuel ratio to lower emissions and increase fuel economy, has made the units too expensive for use on many applications.

Third, throttle response is faster with TBI because the fuel is under pressure at all times to the injector. As a result, the movement of fuel does not have to rely on the changing difference in pressure as in the carbureted systems. All that is required in the TBI system is the opening of the injector, and fuel under pressure sprays out instantly.

Fourth, fuel injection provides not only a precise mixture but a thorough mixing of the air and fuel under a wider variety of engine speeds, loads, temperatures, and driving habits. This will reduce emissions, increase fuel economy, and enhance driveability even during cold engine operation.

Fifth, HC and CO emissions during deceleration can be practically eliminated by the use of fuel injection. TBI, for example, is designed to severely cut back or shut off the fuel when the throttle is released and the vehicle decelerates. This action also conserves fuel. Finally, the TBI system prevents engine run-on by stopping fuel flow after the ignition switch is cut off.

Types of TBI Units

One of three types of TBI units—the single-point, two-point, and the crossfire—can be used to take the place of the carburetor. The single-point unit is used on four-cylinder engines, the two-point on V-6 and V-8 engines, and the crossfire on high performance V-8 engines. In any case, a basic TBI unit consists of two main assemblies, a throttle body and a fuel meter body. The complete assembly is located centrally on the intake manifold on single- and two-point systems.

On the single-point TBI unit, the throttle body

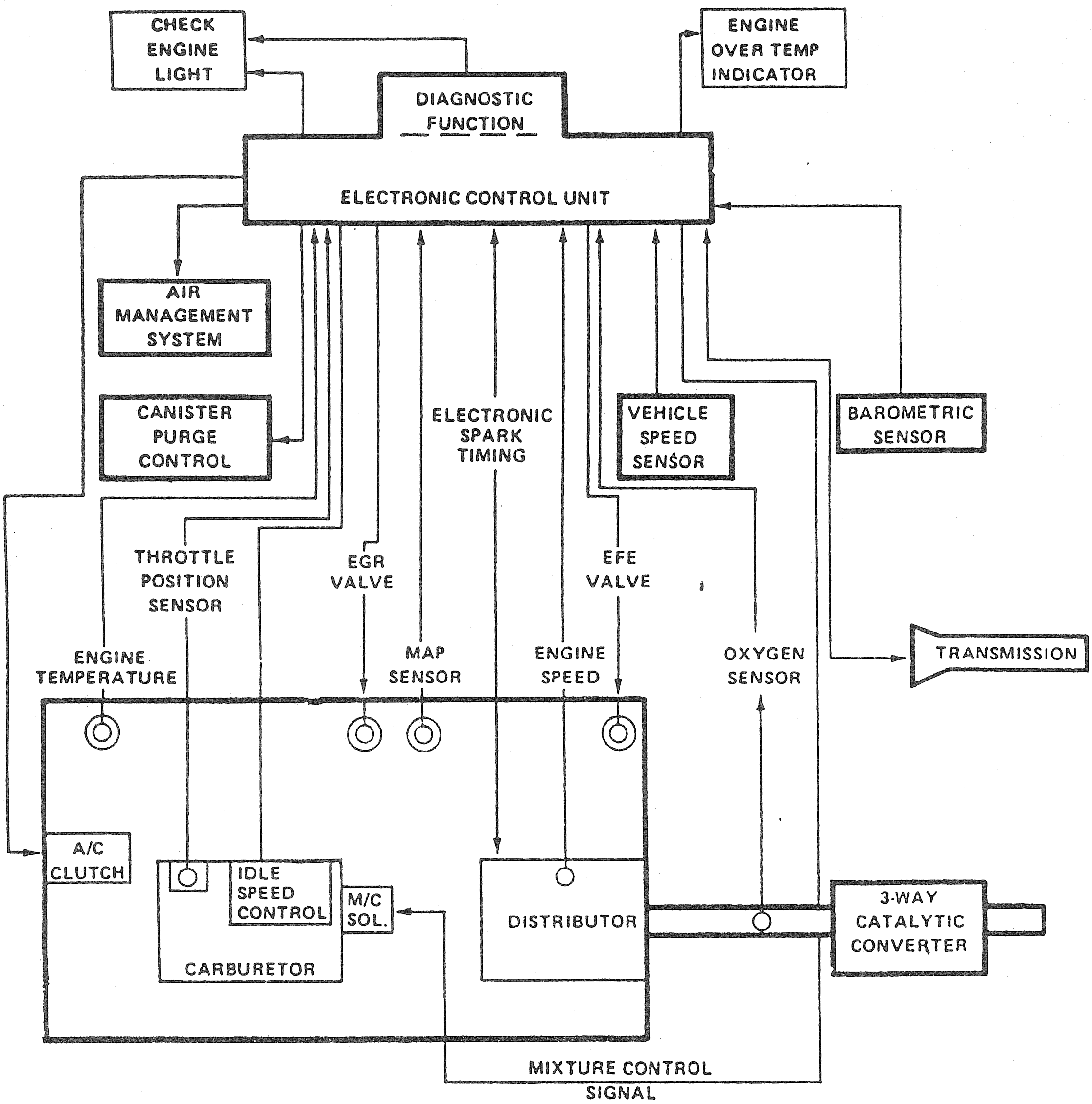


FIGURE 20-37
CCC systems operation.

has one throttle valve that connects to the accelerator pedal linkage and controls the airflow through both assemblies (Fig. 20-38). The fuel metering assembly contains two main components. A single injector meters the proper amount of fuel into the throttle body, as determined by the microcomputer. The pressure regulator maintains fuel pressure to 10 to 12 psi (70 to 83 kPa).

There are two differences between the single- and *two-point units*. That is, the two-point unit has two throttle valves in the lower body and two injectors within the metering assembly instead of one of each as in the single-point units (Fig. 20-39).

The *crossfire system* includes a pair of single-point TBI units (Fig. 20-40). Both mount in tandem as a front and rear unit on a single intake manifold and connect by a common throttle rod to the accelerator pedal. In operation, each unit supplies an exact amount of the air/fuel mixture through a tuned crossover runner in the manifold to the bank of cylinders on the opposite side of the engine. From this type of fuel flow comes the name crossfire injection.

CCC-TBI System Inputs

The microcomputer of the CCC-TBI system receives input signals regarding engine coolant temperature, manifold absolute pressure, oxygen sensor, throttle position, distributor reference, vehicle speed, park/neutral switch, transmission gear switch, air condi-

tioning on or off, ignition crank mode, and fuel pump voltage. Many of the sensors or switches that produce these signals are the same ones used in the CCC-carbureted systems. For this reason, this section will only discuss those that are new or have a different design or function within the TBI system.

Manifold Absolute Pressure Sensor. The MAP sensor used on the TBI application has the same basic design as the one used on carbureted systems. However, with TBI, the ECM is programmed to use the MAP sensor also as a barometric pressure sensor. When the ignition switch is moved to the run position on its way to "crank," the ECM reads the MAP sensor input signal. Since, at this point, the engine has not turned over, the pressure in the manifold is atmospheric.

The ECM stores this reading as barometric pressure and uses it in calculating both the air/fuel mixture and spark timing in its open loop mode. This reading is used until the ignition switch is turned off or until the throttle is moved to wide-open. At this time, manifold pressure again reaches atmospheric, and the ECM records an updated barometric reading.

Throttle Position Sensor. The TP sensor used on the CCC-TBI system is also a potentiometer that develops an input signal based on throttle valve position. However, with TBI, the sensor connects to the end of the throttle shaft (Fig. 20-41) and may be the adjustable or nonadjustable type.

Distributor Reference Pulse. The TBI system also uses the distributor reference pulse signal as an input signal to the ECM. This pulse signals the computer data on engine speed and crankshaft position. Moreover, the ECM uses the signals during its synchronized mode of operation to time the pulsing of the injectors. Therefore, if the ECM fails to receive the reference signal, fuel injection is stopped.

Vehicle Speed Sensor. The vehicle speed sensor on TBI models has one additional function. That is, the ECM uses the signal to help identify a deceleration condition.

Ignition Crank Mode. The TBI system has an input signal that the ECM uses to determine when the engine is cranking over. The signal comes from the circuit that energizes the starting motor solenoid. The ECM uses this and the coolant temperature signal to calculate the correct air/fuel ratio provided by the injectors during engine start-up.

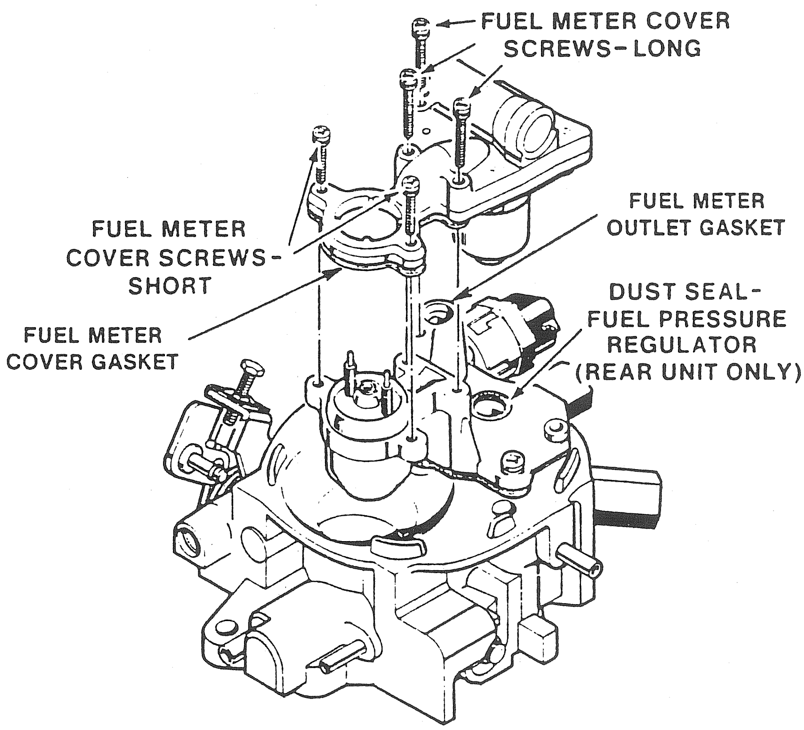
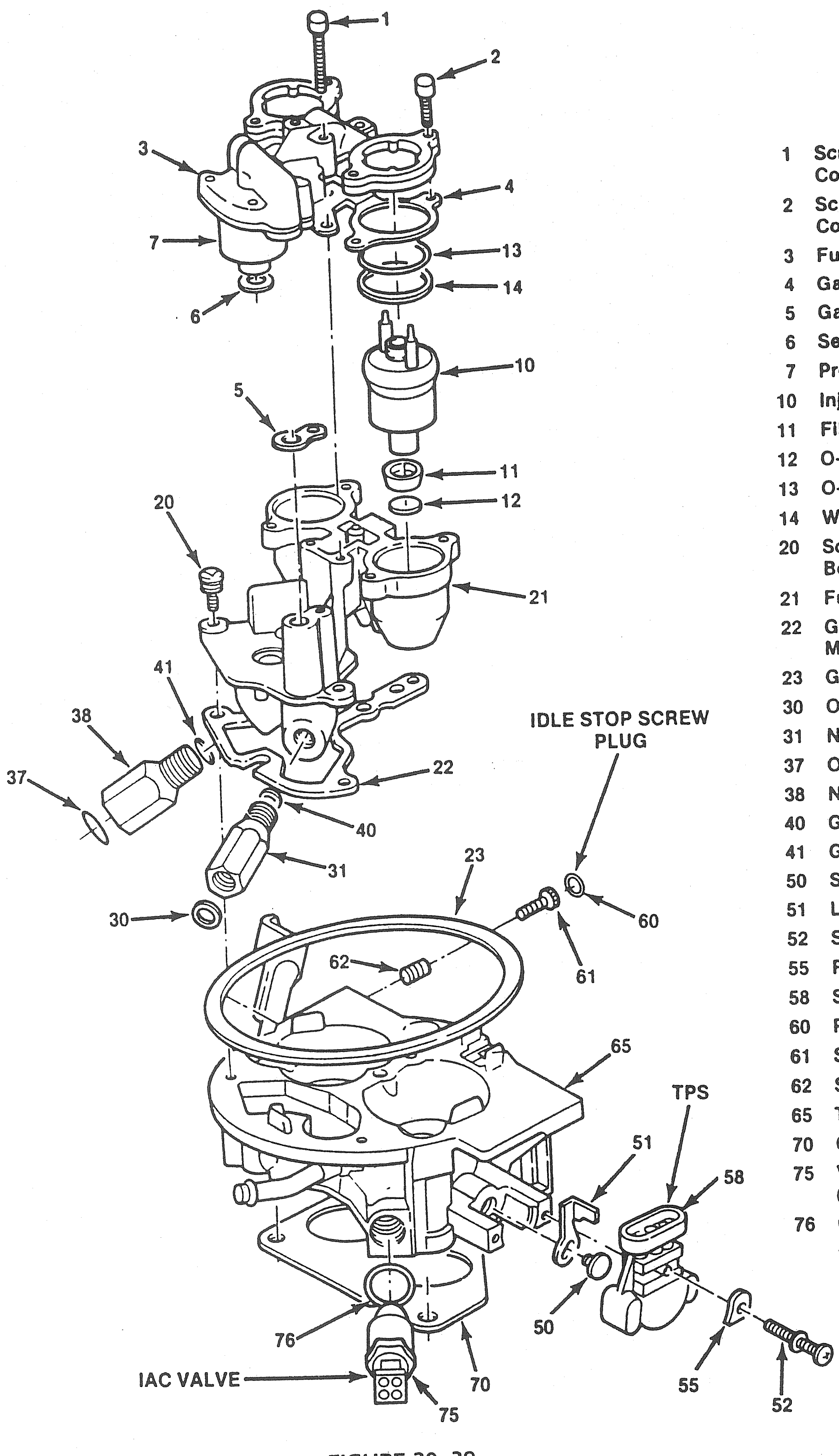


FIGURE 20-38
Single-point throttle body injection (TBI) unit. (Courtesy of General Motors Corp.)



1 Screw Assembly - Fuel Meter Cover Attaching - Long
2 Screw Assembly - Fuel Meter Cover Attaching - Short
3 Fuel Meter Cover Assembly
4 Gasket - Fuel Meter Cover
5 Gasket - Fuel Meter Outlet
6 Seal - Pressure Regulator
7 Pressure Regulator
10 Injector - Fuel
11 Filter - Fuel Injector Inlet
12 O-ring - Fuel Injector - Lower
13 O-ring - Fuel Injector - Upper
14 Washer - Fuel Injector
20 Screw Assembly - Fuel Meter Body - Throttle Body Attaching
21 Fuel Meter Body Assembly
22 Gasket - Throttle Body to Fuel Meter Body
23 Gasket - Air Filter
30 O-ring - Fuel Return Line
31 Nut - Fuel Outlet
37 O-ring - Fuel Inlet Line
38 Nut - Fuel Inlet
40 Gasket - Fuel Outlet Nut
41 Gasket - Fuel Inlet Nut
50 Screw - TPS Lever Attaching
51 Lever - TPS
52 Screw Assembly - TPS Attaching
55 Retainer - TPS Attaching Screw
58 Sensor - Throttle Position (TPS)
60 Plug - Idle Stop Screw
61 Screw Assembly - Idle Stop
62 Spring - Idle Stop Screw
65 Throttle Body Assembly
70 Gasket - Flange
75 Valve Assembly - Idle Air Control (IAC)
76 Gasket - Idle Air Control Valve Assembly

FIGURE 20–39
Two-point TBI unit. (Courtesy of General Motors Corp.)

Fuel Pump Voltage. Some of the TBI systems have a *fuel pump voltage* input signal. This signal comes from the positive side of the fuel pump power circuit. The signal informs the ECM that the fuel pump is in operation.

CCC-TBI System Outputs

During operation, the TBI-ECM provides output command signals to the air management solenoids, canister purge solenoid, EGR solenoids, electronic spark timing, torque converter clutch, CHECK ENGINE light (when necessary), injector solenoids, idle air control assembly, fuel pump relay, cooling fan relay, and air conditioning relay.

As in the case of the input sensors or switches, many of the output devices found in the TBI system are the same as those within carbureted applications. Therefore, only those that are found on TBI systems will be covered.

Injector Solenoid. The fuel injector (Fig. 20-42) contains an electromagnetic device or solenoid. This solenoid, when grounded by the ECM, pulls the plunger or core piece upward. This action allows the spring-loaded ball valve to come off its seat. The open valve permits fuel to flow through a 10-micron filter to the atomizer or spray nozzle. The pressurized fuel is then directed in a conical spray pattern at the walls of the throttle body bore, above the throttle valves.

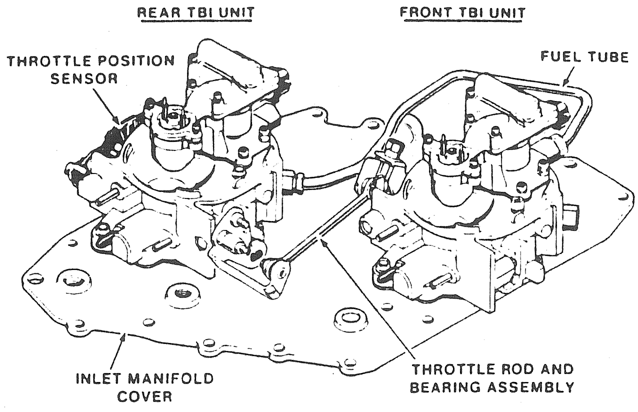


FIGURE 20-40
Crossfire injection. (Courtesy of General Motors Corp.)

An injector, when energized by the ECM, has full battery voltage applied to its solenoid coil until current rises to a reference level of four amperes. Current regulation then takes over, maintaining a hold-in current of one ampere until the ECM turns the injector off. This permits a fast pull-in of the solenoid armature during injector turn-on, yet low current flow during hold-in to prevent the solenoid coil from overheating. The amount of time the ECM energizes the solenoid to open the injector valve is known as its pulse width.

Idle Air Control Assembly. The *idle air control (IAC)* assembly mounts directly in the throttle body

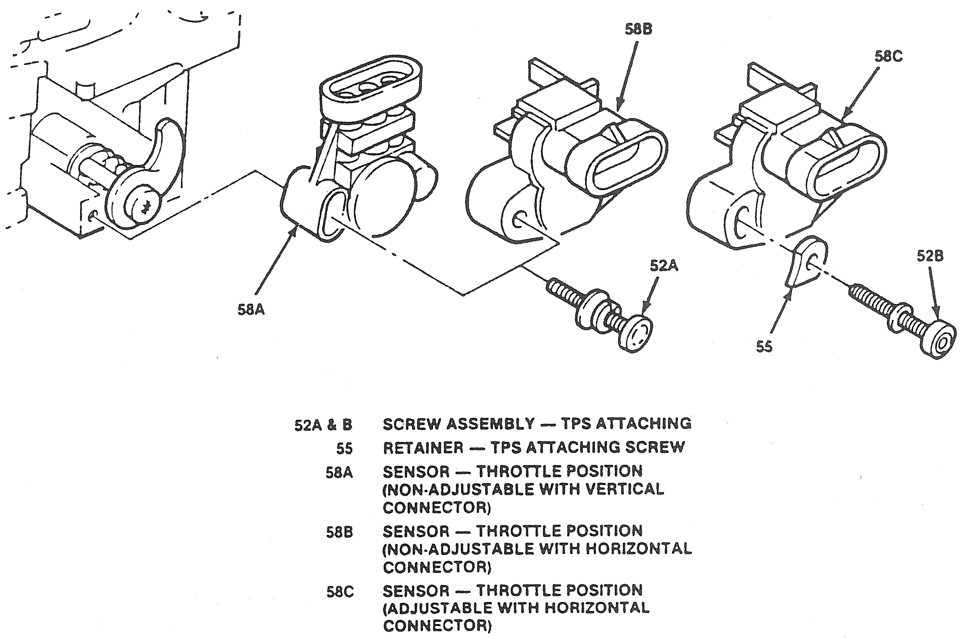


FIGURE 20-41
Typical throttle position sensors. (Courtesy of General Motors Corp.)

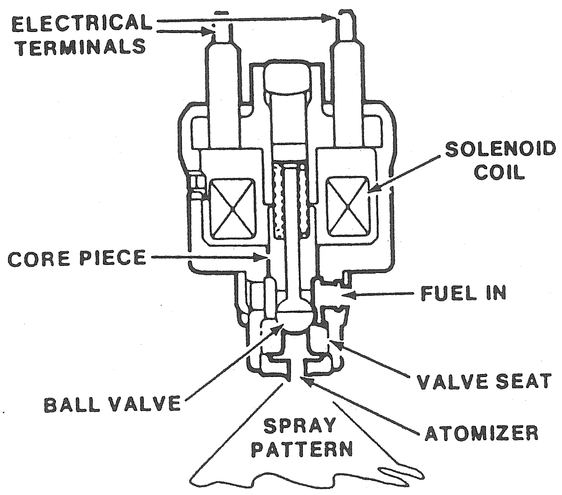


FIGURE 20-42
Typical fuel injector. (Courtesy of General Motors Corp.)

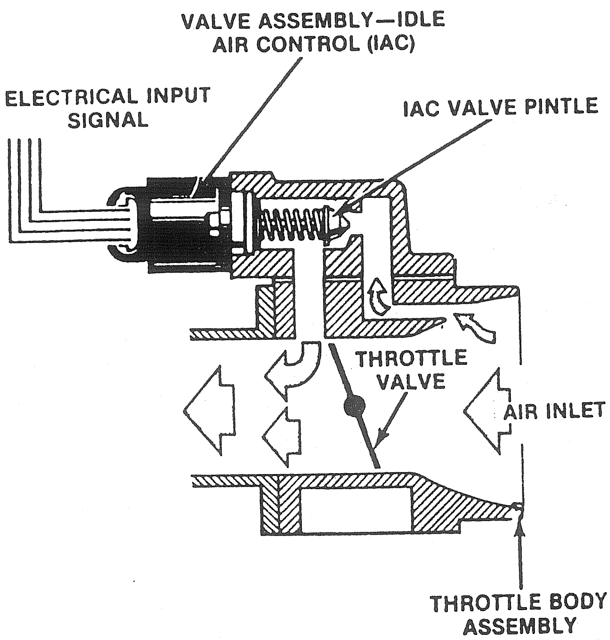


FIGURE 20-43
IAC assembly. (Courtesy of General Motors Corp.)

(Fig. 20-43). Its function is to control idle speed to prevent stalling due to changes in engine load. The IAC performs this function by controlling the amount of air that bypasses the throttle valve and passes directly into the intake manifold. If engine rpm is too low, for example, more air is bypassed around the throttle valve to increase idle speed. If idle speed is too high, less air is bypassed by the IAC assembly.

To control the amount of bypass air, the IAC consists of a four-wire, two-winding reversible stepper motor and pintle valve. The rotational movement in either direction of the motor is changed by means of a worm gear into linear travel (steps) of the attached pintle valve. The pintle valve is located in an air passage leading from one side of the throttle valve to the other.

The ECM can energize the motor to move the pintle any number of steps from fully retracted to fully extended, depending on which of its windings receives power. As a result, the pintle valve controls the amount of air bypassing the throttle valve to increase or decrease the idle speed as necessary.

The actual position of the IAC pintle valve is calculated by the ECM based on battery voltage, coolant temperature, engine load, and engine speed. If engine rpm drops below a specified value with the throttle closed, the ECM senses a near-stall condition. The ECM then calculates a new valve position and energizes the correct IAC motor winding to move the pintle to the new location.

In addition to controlling idle speed, the IAC also aids in the control of HC and CO emissions. During deceleration, the ECM energizes the motor to retract the pintle a calibrated number of steps, depending on vehicle speed. This permits more air to bypass the throttle valve and enter the intake manifold directly. This air helps to reduce hydrocarbon and carbon monoxide emissions that occur due to the rapid closing of the throttle valve during deceleration.

Fuel Pump Relay. The ECM normally controls the operation of the electric fuel pump by means of a *fuel pump relay* that mounts in the engine compartment. When the driver first turns the ignition key on without the engine running, the ECM turns the fuel pump relay on for two seconds (Fig. 20-44). As a result, the pump operates and builds up fuel pressure quickly.

If the engine does not start within two seconds, the ECM deenergizes the solenoid to shut the pump off until the engine starts. The ECM will energize the relay again only after two conditions are met: (1) it receives a REF signal indicating the engine is running, and (2) the driver turns the ignition switch off and then back on.

As a backup system in case of a relay malfunction, the fuel pump can be turned on by one of the two oil pressure switch circuits. One of the switches controls the circuit to the oil pressure indicator or gauge on the instrument cluster. The second switch that is normally open will close when oil pressure reaches about 4 psi (28 kPa). As a result, the circuit to the pump receives power and will operate, even with a defective relay.

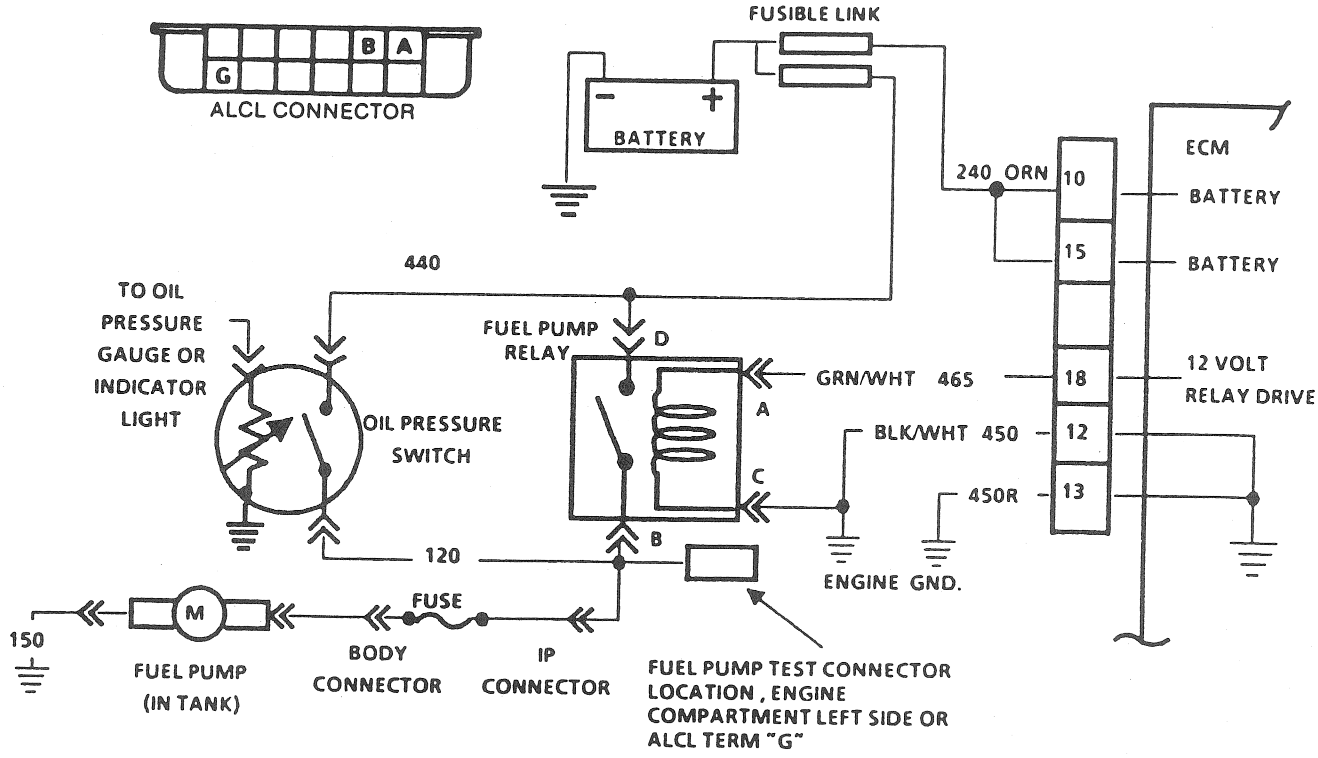


FIGURE 20-44
Fuel pump and relay schematic (Courtesy of General Motors Corp.)

Notice in Fig. 20-44 the fuel pump test connector. Depending on the model and year of the vehicle, it can be located in the engine compartment or in the assembly line communication link under the instrument panel. In any case, the connector is wired into the power circuit to the fuel pump. Therefore, it can be used by a technician to test the circuit for power with a voltmeter.

Cooling Fan Relay. All front-wheel drive vehicles with transversely mounted engines and some others use an electric cooling fan. The fan is used for engine and A/C condenser cooling. The operation of the fan is controlled totally by the ECM by means of a relay, except in the case of microcomputer failure. In this case, the override switch turns on the fan.

The ECM energizes or de-energizes the relay based on input from the coolant temperature sensor, A/C fan control switch, and vehicle speed sensor. The ECM energizes the relay by providing a ground for wire #335 that attaches to Terminal B of the relay (Fig. 20-45). The actual grounding occurs at the fan control output driver transistor within the ECM. With the relay grounded, its internal contacts complete the power circuit to the fan motor. Once the ECM energizes the relay, it will keep the fan on for a minimum of 15 to 30 seconds or until the vehicle speed exceeds about 40 mph.

The ECM energizes the fan through the relay below 40 mph under the following two conditions. First, coolant temperature is over about 223°F (106°C). Second, the A/C has been turned on and the fan control switch, mounted in the compressor, opens with a high A/C pressure of approximately 200 psi (1380 kPa).

Air Conditioning Relay. The ECM controls the operation of the A/C compressor clutch through a relay (Fig. 20-46). When the driver turns on the air conditioning switch, a signal is sent to the ECM. The ECM then provides a relay ground circuit through wire #458 that connects to Terminal C of the relay and an output driver transistor within the microcomputer. With the relay grounded, it energizes and completes the power circuit to the compressor clutch.

However, the ECM does not energize the relay immediately after the driver turns the A/C switch on. The ECM provides a 0.4-second delay period before grounding the relay. This allows the IAC to adjust engine idle speed before the A/C clutch engages. The ECM also breaks the relay ground to disengage the A/C clutch during wide-open throttle operation and if the engine overheats.

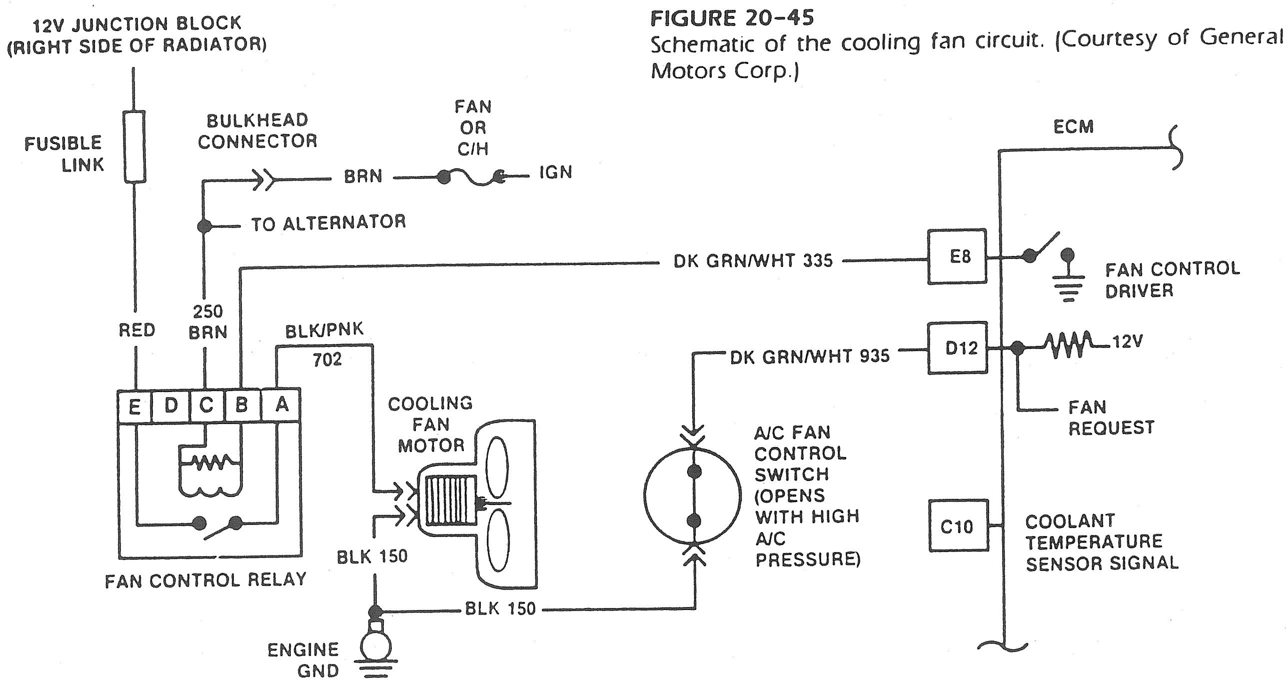


FIGURE 20-45
Schematic of the cooling fan circuit. (Courtesy of General Motors Corp.)

Electronic Control Module

The CCC-TBI system is controlled by an on-board microcomputer, known as the electronic control module (ECM). It is normally located under the instrument panel, above or near the glove compartment (Fig. 20-47). The ECM monitors engine operating and environmental conditions. It then provides output signals that control the air/fuel ratio, ignition timing, engine idle speed, and the operation of various emission control components.

The ECM also performs a number of system diagnostic functions. It can recognize operational problems, alert the driver through the SERVICE ENGINE SOON light, store fault codes, and provide a data stream.

Some fuel injected models have an ECM that uses a PROM and a device called a *CALPAC*. The CALPAC allows for fuel delivery, in case of PROM or ECM failure, so the engine can still operate.

Some newer versions of the ECM consist of two parts, a controller (the processor) and the MEM-CAL. The *MEM-CAL* resembles the PROM and stands for memory calibration unit. This unit contains both the functions of the PROM and CALPAC (see Fig. 20-47).

TBI System Operating Modes

As mentioned, the ECM receives and looks at input signals from a number of sensors before calculating what air/fuel mixture to provide the engine. The quantity of fuel delivered depends on several operating conditions, called modes, which are controlled by the ECM.

Starting Mode. When the driver first turns the ignition switch to on, the ECM energizes the fuel pump relay for two seconds, and the fuel pump builds pressure in the system (Fig. 20-48). As the engine is cranked over for starting, the ECM delivers an injector pulse that is synchronized with each distributor reference signal.

The ECM provides the cranking air/fuel ratio if the throttle position is less than 80 percent open. This air/fuel ratio is determined by the ECM and ranges from 1.5:1 at 32.8°F (36°C) to 14.7:1 at 201°F (94°C). The lower the coolant temperature, the longer is the pulse width (injector on-time) and the richer is the air/fuel mixture. The higher the coolant temperature, the shorter is the pulse width and the leaner is the air/fuel charge.

Clear Flood. If the engine becomes flooded for any reason, the ECM is programmed to clear the condition. To activate this mode, the driver depresses the throttle pedal to wide open or past 80 percent of its travel. The ECM then directs output injector pulses at a rate that provides an air/fuel ratio of 20:1 (Fig. 20-49).

The ECM maintains this injector pulse width

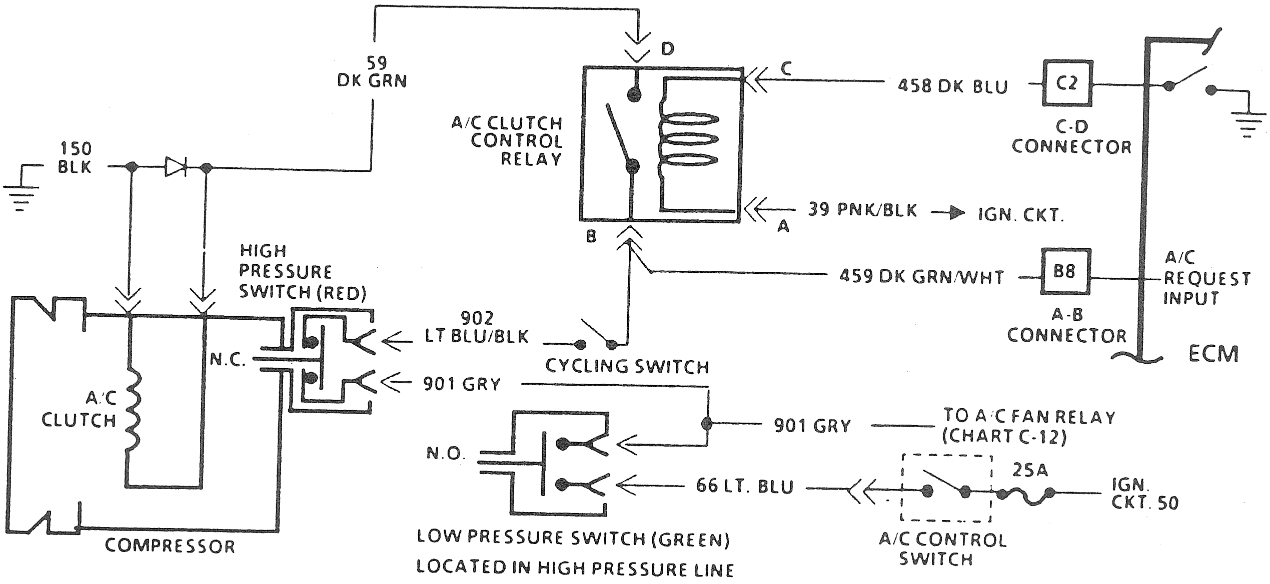


FIGURE 20-46
A/C relay circuit schematic. (Courtesy of General Motors Corp.)

as long as the TP sensor signals that the pedal is still in this position and the engine rpm is less than 600. If the throttle position is changed to less than 80 percent, the ECM immediately alters the injector pulse width to provide an air/fuel ratio based on coolant temperature.

Open Loop Run Mode. After the engine starts and the REF signal indicates at least 400 rpm, the ECM operates in *open loop run mode* (Fig. 20-50). At this time, the ECM ignores the signal from the oxygen sensor and calculates the air/fuel ratio and engine timing based on inputs from the coolant and MAP sensors as well as the REF signal.

The system stays in open loop until the following conditions are met:

- The oxygen sensor produces varying voltages indicating it is at a normal operating temperature of 600°F (315°C).
- The coolant temperature rises above a specified temperature of about 150°F (65.6°C).
- A specific amount of time (about 2.5 minutes) elapses after starting the engine.

Note: The specific values for the above conditions do vary with different engines. These values are stored either in PROM or MEM-CAL.

During open loop, the torque converter clutch solenoid remains de-energized and the IAC controls idle speed. The operating condition of the remaining ECM output actuators is as follows. The EGR solenoid is de-energized. The air management solenoids permit pump air to flow into the exhaust ports. The canister purge solenoid is de-energized, and the cooling fan relay is de-energized. The A/C relay is energized or de-energized by driver demand. The EFE heater relay is energized, and system diagnostics are used as needed.

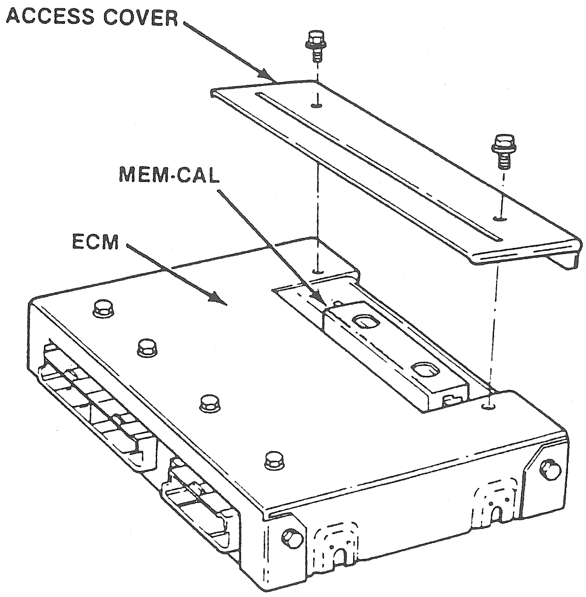


FIGURE 20-47
ECM and MEM-CAL. (Courtesy of General Motors Corp.)

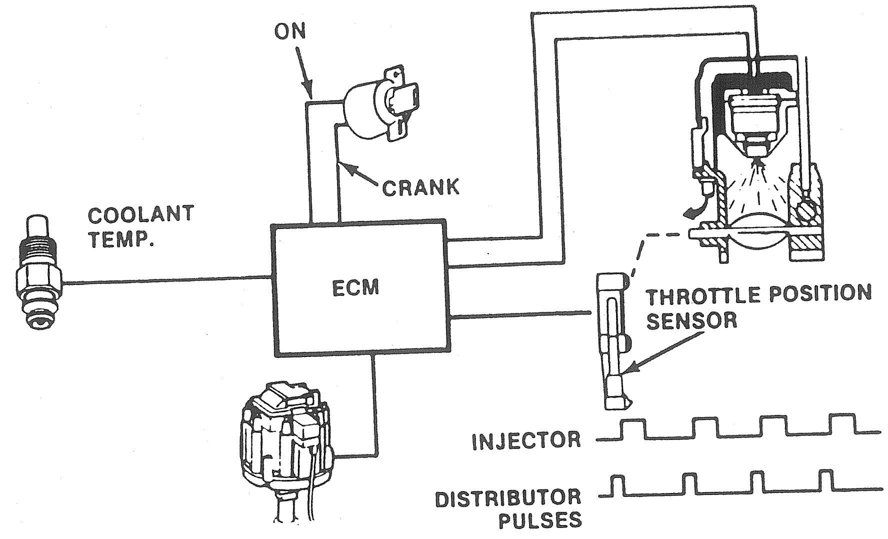


FIGURE 20–48
Air/fuel ratio during engine cranking. (Courtesy of General Motors Corp.)

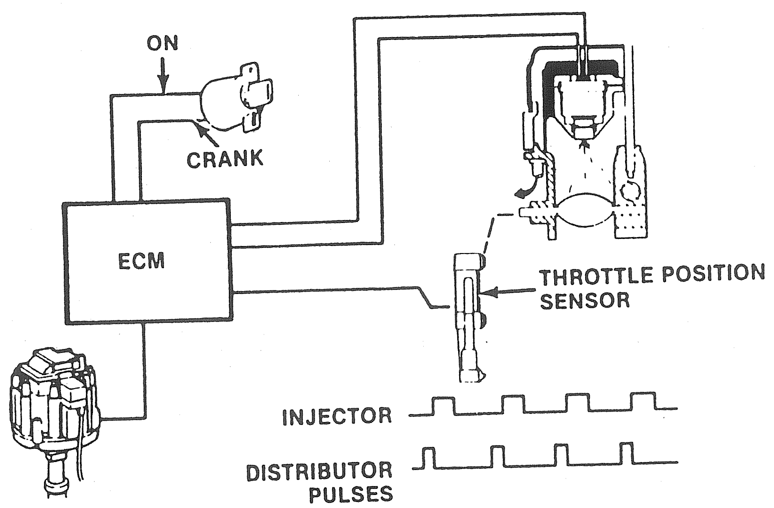


FIGURE 20–49
Fuel control during engine flooding. (Courtesy of General Motors Corp.)

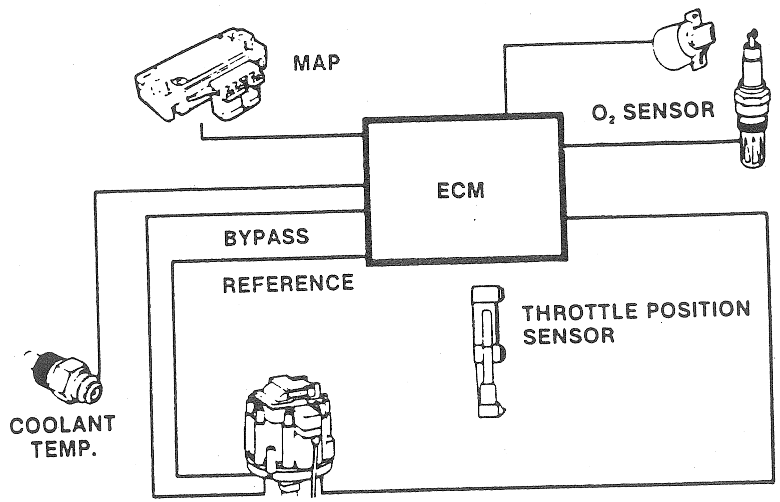


FIGURE 20–50
Open loop run mode. (Courtesy of General Motors Corp.)

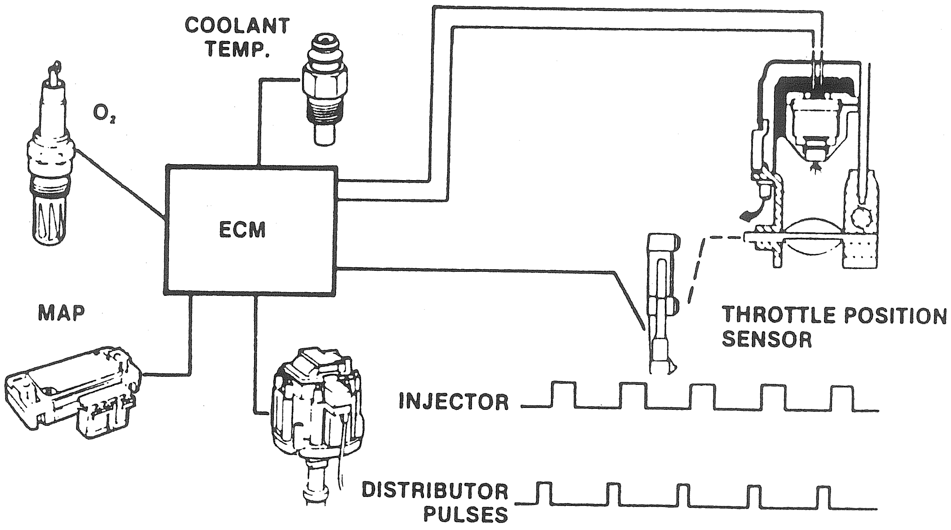


FIGURE 20-51
Closed loop run mode. (Courtesy of General Motors Corp.)

Closed Loop Run Mode. When the operating conditions mentioned above have been met, the ECM enters its *closed loop run mode.* During closed loop, the ECM calculates the injector pulse width to maintain an air/fuel ratio as close as possible to 14.7:1. In calculating the correct pulse width, the ECM uses input signals from the oxygen sensor, MAP sensor, distributor, TP sensor, and coolant temperature sensor (Fig. 20-51).

Output signals from the ECM also provide canister purging; exhaust gas recirculation; correct ignition timing; cooling fan operation, as needed; TCC clutch application at the correct vehicle speed and gear ratio; proper idle speed; pump air to the downstream location; A/C operation on driver command; shutdown of the EFE heater; and system diagnostics as needed. System diagnostics include values for integrator and block learn functions of the ECM, which represent injector on-time. Additional information on these functions is covered in the next chapter.

Acceleration Enrichment Mode. When the engine is accelerated off idle, the opening throttle valve causes a reduction in manifold vacuum accompanied by a rapid increase in airflow. The MAP sensor signals the ECM of the reduction of engine vacuum (the increase in mean absolute pressure). At the same time, the TP sensor signals the increase in throttle opening. From these signals, the ECM calculates the amount of fuel needed and changes the injector pulse width accordingly. This prevents the engine from stumbling due to a lean air/fuel mixture (Fig. 20-52).

Deceleration Leanout Mode. As the engine decelerates, a leaner air/fuel ratio is necessary in order to reduce HC and CO emissions. To accomplish the leaner mixture, the ECM adjusts injector pulse width time based on the input signals from the MAP and TP sensors (Fig. 20-53). At this time, the MAP sensor signal indicates an increase in manifold vacuum (decrease in mean absolute pressure), while the TP sensor signal shows the reduction in throttle opening. As a result of these signals, the injector air/fuel ratio is reduced to compensate for the remaining fuel within the intake manifold. In this way, the ECM maintains the ratio of 14.7:1 as closely as possible, even on deceleration.

Deceleration Fuel Cut-Off Mode. Under certain conditions, the ECM will override the deceleration leanout mode and cut off the fuel to the engine. This situation will occur during an extreme deceleration condition. The ECM will cut off the injector fuel flow bases on MAP, TP, and rpm signals from the distributor. The ECM makes the cut-off decision after comparing the sensor input signal values against those stored in PROM or MEM-CAL.

Battery Voltage Correction Mode. Battery voltage correction takes place in all ECM operating modes. Battery voltage correction compensates for variations in system voltage to the fuel pump and injectors that can occur if a combination of electrical accessories are being used, the battery is defective, or the alternator output is low. In any case, the voltage variations can cause the injector pulse width to change slightly. This effects the amount of fuel in-

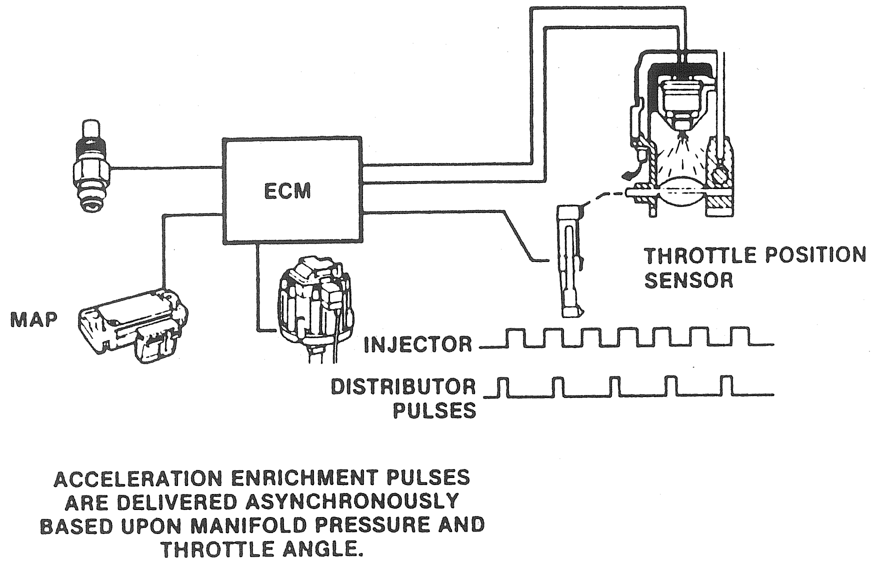


FIGURE 20-52
Acceleration enrichment mode. (Courtesy of General Motors Corp.)

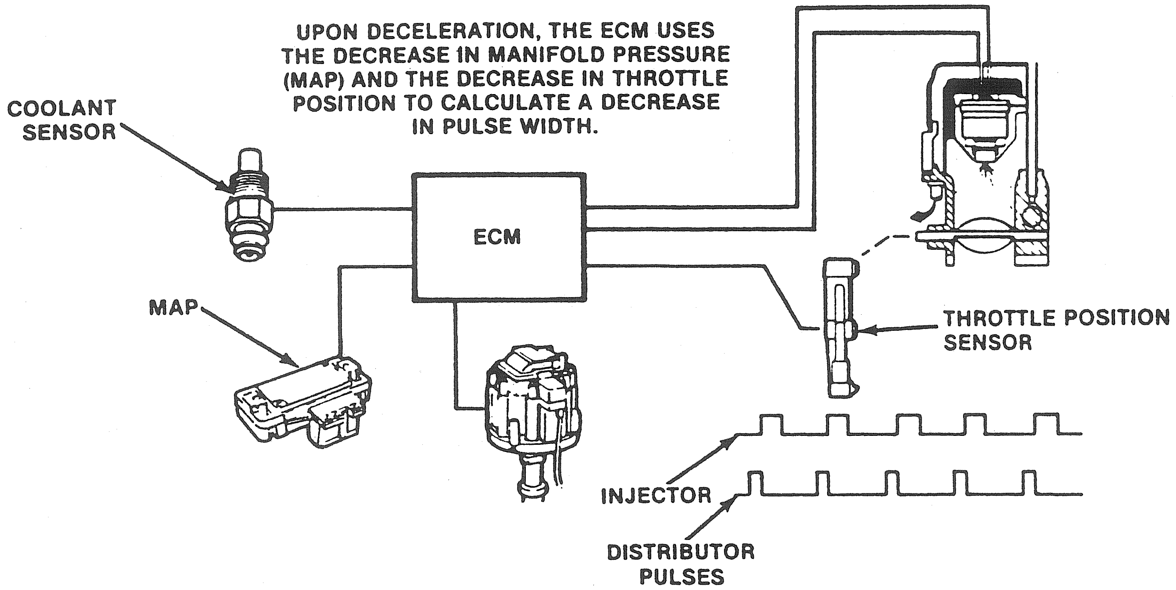


FIGURE 20-53
Deceleration lean-out mode. (Courtesy of General Motors Corp.)

jected during a given pulse width period.

The ECM is programmed to compensate for this problem by modifying the pulse width by a correction value contained within PROM or MEM-CAL. For example, when battery voltage decreases, pulse width increases (Fig. 20-54).

Shutdown Mode. When the engine is shut down, the fuel flow from the injectors is cut off. This occurs for two reasons. First, with the ignition switch turned off, power to the injectors is terminated. Second, once engine rpm drops below a given value, the ECM no longer receives a distributor REF signal. Without this signal, even with the ignition switch on, the ECM does not energize the injectors.

The shutdown mode thus prevents several negative conditions. For instance, the engine cannot diesel with the fuel shut off. Also, flooding of the engine is prevented.

Back-Up Mode. The ECM has a *back-up mode* programmed into either CALPAC or MEM-CAL. This

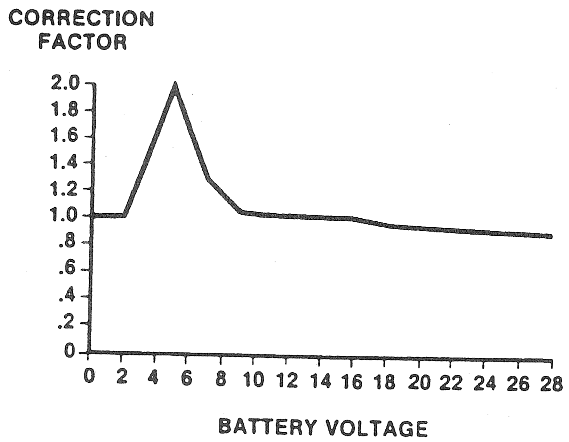


FIGURE 20–54
Voltage correction mode. (Courtesy of General Motors Corp.)

program allows the ECM to provide the timing and pulse width signals for the injectors using only the distributor REF, CT, and TP input signals (Fig. 20-55). This mode is used only when the ECM cannot operate normally and is sometimes referred to as the "*limp home*" mode.

The ECM functions within the back-up mode if any one or a combination of the following occurs—if the ECM voltage is less than nine volts, if the cranking voltage is below nine volts, if PROM is missing or not functioning, and if the ECM circuit fails to ensure computer operating pulses (COP).

The back-up mode is power fed from the ignition switch and controls only the fuel pump relay and pulse width of the injectors. As a result, the engine runs erratically and a fault code is set in ECM memory.

20-5 CCC-PFI SYSTEM—DOMESTIC AND IMPORTED

General Motors introduced the *port fuel injection (PFI) system* on a limited basis in 1984 (Fig. 20-56). Since that time, the system has been used by the various General Motor's domestic car divisions on a number of engine applications. In addition, PFI is also used on a number of vehicles manufactured for General Motors import by corporations outside the United States. These corporations include Suzuki, Isuzu, and Nummi.

System Names

There are four names provided by the various General Motor's divisions for the PFI system. These are

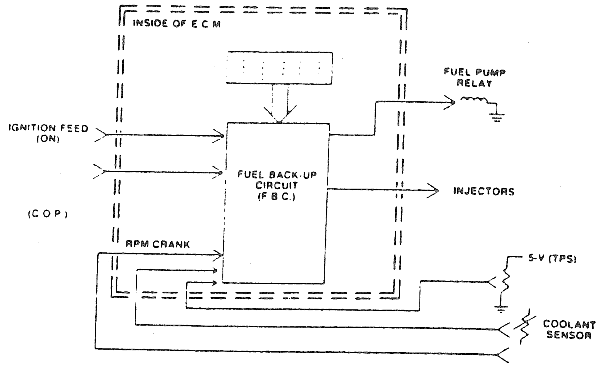


FIGURE 20–55
ECM back-up mode schematic. (Courtesy of General Motors Corp.)

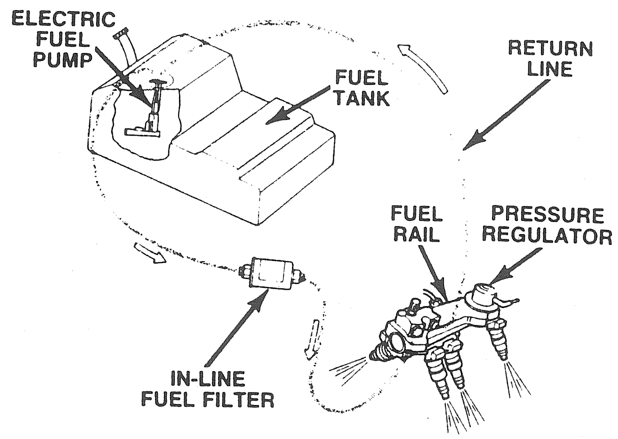


FIGURE 20–56
PFI system. (Courtesy of General Motors Corp.)

multiport fuel injection, port fuel injection, tuned fuel injection, and sequential fuel injection. The multiport fuel injection (MFI) and the port fuel injection (PFI) systems both have one injector per cylinder, positioned within the manifold in each intake port (Fig. 20-57). The airflow through the intake manifold on three, four, and V-6 engines is controlled by a throttle body with a single bore.

On both systems, the ECM pulses all the injectors simultaneously during every crankshaft revolution. The fuel sprayed into the port while the intake valve is closed is simply stored there until it opens.

The *tuned port injection (TPI) system* is the same as MFI and PFI except for two important differences (Fig. 20-58). First, the intake manifold has tubular runners instead of rectangular ones. Each runner is tuned (i.e., has the same shape, length, and cross-sectional area) to channel air smoothly to each intake valve. This design maximizes volumetric efficiency without turbocharging, thus improving engine performance.

Second, the throttle body that meters the air

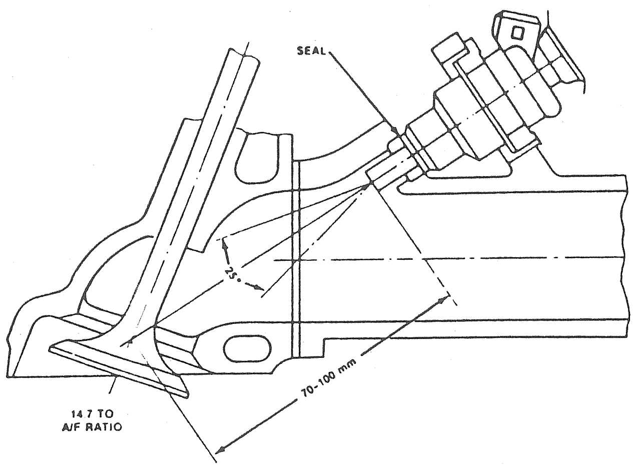


FIGURE 20-57
PFI fuel injector installation. (Courtesy of General Motors Corp.)

into the intake manifold has two bores. This helps meet the extra air flow requirements of the V-8 engines on which the system is installed.

The *sequential fuel injection (SFI) system* is installed on selective 3.8-liter applications. In this system, the ECM pulses all the injectors one-by-one in the spark plug firing order. The fuel injections are therefore mixed with the incoming air to produce the charge for each combustion chamber.

PFI Advantages

The PFI system provides many advantages over TBI including the following:

- Improved fuel economy. The PFI system improves fuel economy by providing precise fuel distribution. In addition, axle ratios can be optimized without adversely affecting vehicle performance.
- Lower exhaust emissions. Engines with PFI produce less exhaust emissions due to improved air/fuel distribution, leaner operation during warm-up, and improved airflow sensing.
- Better throttle response. This is the result of injector installation in each intake port, which eliminates the time lag waiting for the air/fuel mixture to fill the intake manifold.
- Improved vehicle performance. This results because the air/fuel mixture is not preheated in the intake manifold, thus allowing a dense charge and, consequently, more power. Since the mixture is not preheated, there is no need for the EFE system or the thermostatically controlled air cleaner.

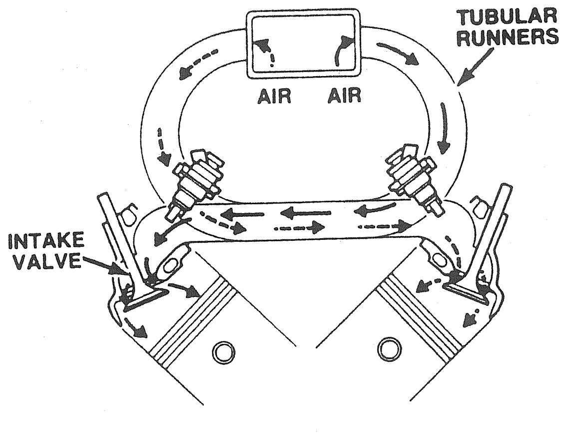


FIGURE 20-58
TPI system. (Courtesy of General Motors Corp.)

CCC-PFI System Inputs

The ECM for a typical CCC-PFI system receives a number of the same input sensor signals as it did with TBI. These identical inputs include A/C on and off, engine coolant temperature, engine crank, exhaust oxygen content, distributor reference (some PFI systems only), manifold absolute pressure, park/neutral switch, system voltage, throttle position, transmission gear position, and vehicle speed.

However, there are a few ECM inputs that the PFI system requires and some others, like a number of those listed above, are used on certain applications. The additional inputs include cruise control on and off, crankshaft and camshaft position, power steering load, mass air flow, and manifold air temperature.

Cruise Control Input. The ECM receives an input signal from the cruise control module whenever the system is engaged. The ECM uses this signal to modify its control of the torque converter clutch.

Crankshaft and Camshaft Sensor Input. The PFI system applications that utilize the distributorless ignition system require a crankshaft and camshaft position sensor. These units may be separate or combined into one assembly. In either case, the sensors provide the ECM with input signals relative to crankshaft speed and the top dead center (TDC) position of the first cylinder. Additional information on these sensors may be found in Chapter 10.

Power Steering Switch Input. The *power steering switch* input signal enables the ECM to compensate

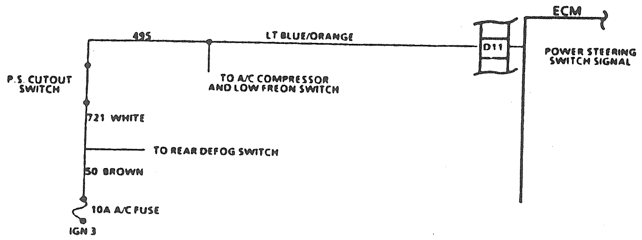


FIGURE 20-59
Power steering switch circuit. (Courtesy of General Motors Corp.)

for the load placed on the engine by the power steering pump. This load occurs when the pump pressure is high during increased system demand periods, such as when parking the vehicle. The power steering switch is normally closed and is opened by high power steering pressure.

When such high pressure conditions occur, the switch opens to break the 12-volt signal from Circuit 50 to the ECM (Fig. 20-59). With the loss of this signal, the ECM, in turn, momentarily de-energizes the A/C compressor clutch and energizes the IAC to increase idle speed.

Mass Air Flow Sensor Input. The *mass air flow (MAF) sensor* is a thermo measuring device that monitors the amount of air entering the induction system. It is also capable of compensating for changes in altitude and humidity, which can affect normal airflow. Using the input signals from the MAF sensor, the engine coolant temperature, and rpm, the ECM can calculate the exact amount of fuel required to provide a 14.7:1 air/fuel ratio. The ECM also uses the above input signals and the signal from the air temperature sensor to determine the amount of spark advance required.

The AC-type MAF (Fig. 20-60) consists of a screen to break up the air flow, a ceramic resistor to measure the temperature of the incoming air, a heated foil sending element, and the electronic module, which rivets to a porcelain-coated steel circuit board.

In operation, after the air passes through the screen, it flows over the air temperature resistor. The sample tube then directs some of the air to flow over the heated foil sensing element. The power to heat this element comes from either a fused circuit or a relay, depending on application.

MAF sensor circuitry controls the current flow through the foil sensing element to keep its temperature at 167°F (75°C), as measured by the temperature sending resistor. The amount of current used

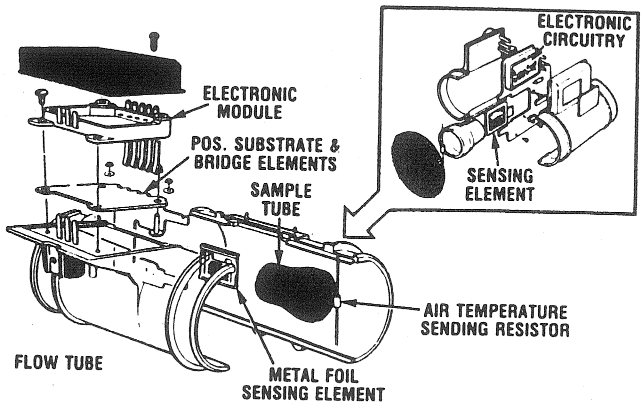


FIGURE 20-60
MAF sensor construction. (Courtesy of General Motors Corp.)

to maintain the foil element at 167°F (75°C), after it is cooled by the air moving over it, is used as the measuring medium for mass air flow.

Electronic circuitry within the MAF module converts the value of the changing circuit current flow into a digital signal with a frequency that ranges from 30 hertz to 150 hertz. The digital signal is then sent to the ECM to be used to calculate engine load changes. For example, an increase in air mass (and an indication that the engine is being placed under a load) causes a rise in signal frequency.

The ECM then compares the MAF frequency signal to data stored in the look-up table programmed in memory (Fig. 20-61). After locating a value in grams per second that corresponds to the MAF signal, the ECM uses it in calculating the air/fuel ratio.

Manifold Air Temperature Sensor. The *manifold air temperature (MAT) sensor* is not used on all PFI applications. However, it will be found on those vehicles that use a MAP sensor input to the ECM for determining mass airflow rate, instead of from the MAF.

In any case, the MAT is a thermistor-type sensor that threads into the intake manifold where its tip is exposed to the airflow (Fig. 20-62). The ECM applies a reference voltage of five volts to the sensor through a resistor. Since the MAT is a thermistor, its resistance changes with increases or decreases in temperature. Consequently, when the air is cold, the sensor resistance is high, and the ECM receives a high MAT input signal. On the other hand, if the air is warm, the sensor resistance is low, and the ECM receives a low MAT signal.

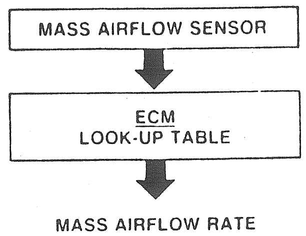
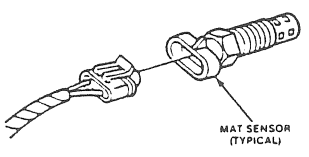


FIGURE 20-61
Mass airflow measurement. (Courtesy of General Motors Corp.)



MAT SENSOR		
TEMPERATURE TO RESISTANCE VALUES (APPROXIMATE)		
°F	°C	OHMS
210	100	185
160	70	450
100	38	1,800
70	20	3,400
40	4	7,500
20	−7	13,500
0	−18	25,000
−40	−40	100,700

FIGURE 20-62
MAT sensor. (Courtesy of General Motors Corp.)

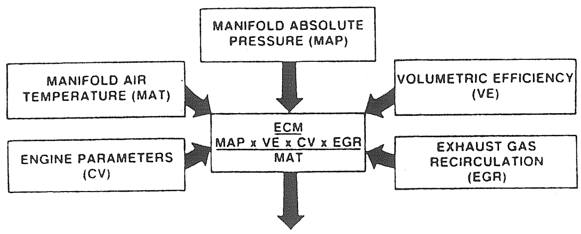


FIGURE 20-63
Speed-density technique. (Courtesy of General Motors Corp.)

By monitoring the MAT sensor signal voltage, the ECM knows the temperature of the air within the intake manifold. The ECM then uses this signal to compensate the mass airflow rate based on temperature.

Speed-Density Technique for Determining Mass Airflow. As mentioned, a number of PFI applications use the MAT and MAP sensor inputs for determining mass airflow rate (Fig. 20-63). This is known as the *speed-density technique*. In this situation, the ECM calculates the airflow rate using

- the MAP signal that indicates changes in intake manifold pressure.
- the MAT signal that shows changes in intake manifold air temperature.
- sensor inputs representing given engine operating parameters such as rpm and throttle position.
- programmed estimates of the engine's volumetric efficiency.
- programmed estimates of EGR flow rate. This is necessary because the exhaust gas displaces a percentage of the air/fuel charge.

CCC-PFI System Outputs

As in the case of the PFI system inputs, many of its ECM outputs are the same as those found in TBI configurations. The outputs, which are nearly the same, include the canister purge solenoid, electronic spark timing signal, idle air control motor, torque converter clutch, fuel pump relay, air conditioning clutch, engine cooling fan relay, air management solenoids, and system diagnostics.

The output devices that have design changes include the injectors and EGR valve.

Fuel Injectors. The PFI fuel injectors are installed between the fuel rails and the intake manifold (Fig. 20-64). The *fuel rail assembly* holds the injectors in position and provides them with the fuel needed for engine operation. The assembly shown in this illustration connects together by front and rear crossover tubes, which are sealed with O-rings. Each side rail is bolted to the intake manifold in several places.

Each injector has a two-wire connector. One wire supplies voltage to the injector solenoid when the ignition key is turned on. The second is a ground wire that connects to the ECM. An output command signal from the ECM controls this ground to complete the circuit and pulse the injector.

The injectors themselves are somewhat different in design than those used with TBI but operate in much the same manner (Fig. 20-65). The PFI injector has a solenoid-operated pintle valve that operates against a seat. The pintle is specially ground to provide a good seal. A diffuser located below the valve seat provides the atomized fuel spray pattern.

Each injector is slip-fitted into the fuel rail and is sealed to it with an O-ring. The injectors are then locked to the rail by means of retaining clips. All injectors are also sealed at the intake manifold with an O-ring. Therefore, the upper O-rings seal against fuel leakage at the rail, while the lower ones prevent a vacuum leak at the manifold. All the O-rings also provide thermal insulation, preventing the formation of vapor bubbles. This improves hot start performance.

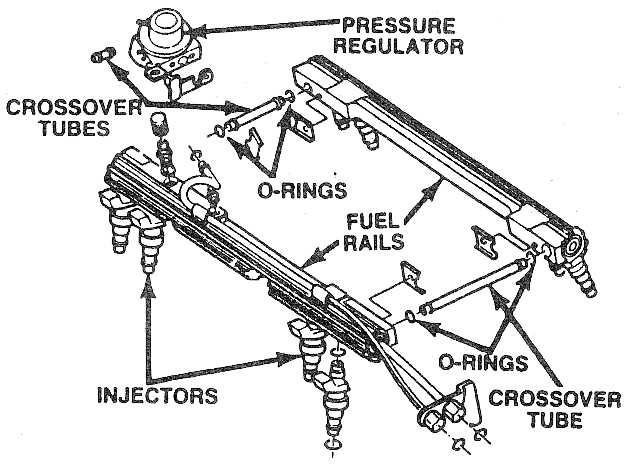


FIGURE 20-64
Fuel rail assembly. (Courtesy of General Motors Corp.)

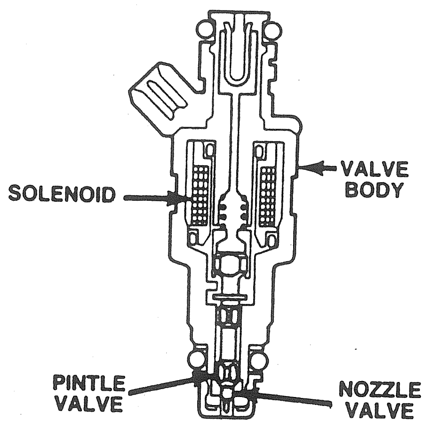


FIGURE 20-65
Typical PFI injector. (Courtesy of General Motors Corp.)

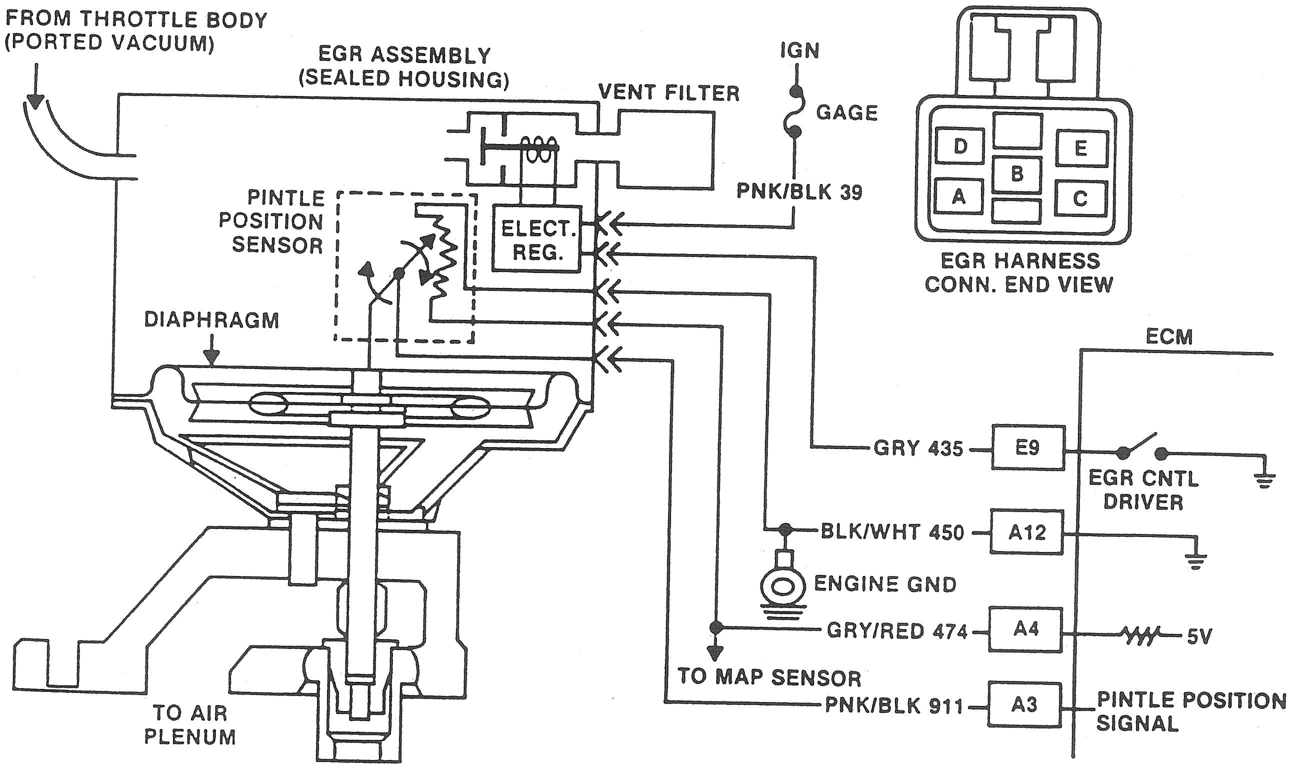


FIGURE 20-66
Integrated EGR valve. (Courtesy of General Motors Corp.)

EGR Valve. Some PFI applications use an *integrated electronic EGR valve* (Fig. 20-66). This unit consists of the EGR valve, vacuum control assembly, and pintle sensor. The valve itself functions similar to the ported units described earlier that use a remote vent solenoid.

The EGR solenoid contains a normally open valve that controls the venting of the diaphragm vacuum signal to the atmosphere. By energizing the solenoid, the vent is closed and the vacuum signal can act on the EGR valve diaphragm.

A voltage regulator is contained within the control assembly base. This unit converts the ECM signal to varying levels of current flow to the solenoid, thereby providing different amounts of EGR flow.

The ECM output command to the regulator is in the form of a pulse width modulated signal. This signal, via the regulator, then turns the solenoid on and off many times a second based on air flow, throttle position, and engine rpm.

This assembly also has a *pintle position sensor.* This sensor is a potentiometer that provides an output voltage signal that the ECM uses to determine if the EGR pintle valve is moving.

PFI ECM

The ECM for the PFI system has about the same design and operates in much the same manner as the one used in the TBI applications. The only difference lies in the programming. For example, the ECM for the PFI system has to be programmed to energize additional injectors and pulse them all either once every crankshaft revolution or sequentially in the engine's firing order.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. Describe the difference between the conventional and tuned PFI systems [20-5].
2. What are the functions of the CCC system [20-1]?
3. Outline the advantages of using TBI [20-4].
4. Why is it necessary to direct pump air away from the exhaust manifolds after an engine is warmed up [20-2]?
5. Name the component parts of an ECM [20-3].

REVIEW

1. Which PFI EGR valve incorporates a pintle sensor [20-5]?
   a. integrated type
   b. separate ported design
   c. electric operated type
   d. both b and c
2. Oxygen sensor voltage should be less than ____________ volt if the air/fuel ratio is lean [20-1].
   a. 0.90
   b. 0.70
   c. 0.65
   d. 0.45
3. PFI injectors are installed between what two components [20-5]?
   a. intake manifold and fuel rails
   b. fuel rails and throttle body
   c. intake manifold and throttle body
   d. none of these
4. Engine calibration codes are stored where in the ECM [20-3]?
   a. in RAM
   b. in the microprocessor
   c. in ROM
   d. in PROM
5. The EST signal is not used by the ECM during engine [20-2]
   a. acceleration.
   b. start-up.
   c. wide-open throttle operation.
   d. deceleration.
6. If the ECM uses the speed-density method of determining mass airflow, it uses input from what sensor(s) [20-5]?
   a. MAF
   b. MAT
   c. MAP
   d. both b and c
7. The CTS is what type of sensor [20-1]?
   a. thermistor
   b. potentiometer
   c. voltage-generating
   d. piezoelectric
8. The cooling fan will not usually operate above what vehicle speed [20-4]?
   a. 20 mph
   b. 30 mph
   c. 40 mph
   d. 50 mph

9. How many solenoid operated valves are necessary to control pump air in systems having dual-bed catalytic converters [20-2]?
   a. one
   b. two
   c. three
   d. four

10. Which PFI sensor measures the current required to heat an element [20-5]?
    a. MAT
    b. MAP
    c. MAF
    d. TPS

11. The CCC-carbureted TP sensor provides a ____________-volt signal to the ECM at wide-open throttle [20-1].
    a. five
    b. three
    c. two
    d. one

12. A camshaft sensor is used in which system [20-5]?
    a. CCC-carbureted
    b. CCC-TBI
    c. some PFI systems
    d. all of these

13. Where is the TCC solenoid located [20-2]?
    a. inside the converter
    b. within the automatic transmission
    c. in the ECM
    d. none of these areas

14. What sensor monitors changes in altitude [20-1]?
    a. BARO
    b. vacuum
    c. TP
    d. both a and b

15. In the TBI and PFI systems, low battery voltage affects the [20-4]
    a. injector pulse width.
    b. TP sensor signal.
    c. oxygen sensor signal.
    d. canister purge operation.

16. The sensor that uses an LED is the [20-1]
    a. MAP.
    b. VS.
    c. TP.
    d. vacuum.

17. In some ECMs used for fuel injection applications, what replaces the PROM [20-4]?
    a. CALPAC
    b. MEM-CAL
    c. RAM
    d. ROM

18. A 90 percent M/C solenoid duty cycle provides [20-2]
    a. a very rich mixture.
    b. a very lean mixture.
    c. the ideal air/fuel mixture of 14.7:1.
    d. a mixture of cold engine starting.

19. In order for the TBI system to operate in closed loop, what sensors must be at a specific operating temperature [20-4]?
    a. TP
    b. oxygen
    c. CT
    d. both b and c

20. What type of device is the M/C solenoid [20-2]?
    a. vacuum
    b. electromechanical
    c. mechanical
    d. electrical

21. If the oxygen sensor temperature is less than 600°F, the engine operates in which mode [20-3]?
    a. open loop
    b. closed loop
    c. shutdown
    d. limp-in

22. If the ECM-controlled EGR system has only one solenoid valve, it acts to control [20-2]
    a. venting of the ported signal.
    b. the shutdown of the ported signal.
    c. the vacuum from an auxiliary source.
    d. none of these.

23. How does the IAC change idle speed [20-4]?
    a. by moving the throttle valve open
    b. by supplying air around the throttle valve
    c. by supplying additional fuel
    d. both b and c

24. Which EFE system uses a relay [20-2]?
    a. coolant type
    b. exhaust heat type
    c. heater grid type
    d. both a and b

25. How are injectors energized by the ECM [20-4]?
    a. by providing a ground circuit for each
    b. by providing voltage to each
    c. both a and b
    d. neither a nor b
26. The ECM energizes the purge control solenoid by [20-2]
    a. sending power to the solenoid.
    b. sending power to a relay.
    c. grounding the solenoid.
    d. both a and c.
27. What sensor in the TBI system acts as a BARO [20-4]?
    a. TP
    b. CT
    c. MAP
    d. REF
28. A four-cylinder engine uses what type of TBI unit [20- 4]?
    a. crossfire
    b. single-point
    c. two-point
    d. both a and b

Chapter 21

TESTING TYPICAL GENERAL MOTORS COMPUTERIZED ENGINE CONTROL SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- demonstrate a working knowledge of the various pieces of equipment used in diagnosing the computer command control (CCC) system.
- explain how to perform diagnostic and performance tests on the CCC system.
- locate the cause of driveability complaints by following diagnostic guides.
- pull out and use the trouble codes in locating the cause of CCC malfunctions.
- locate the cause of a problem in situations where there are no trouble codes in ECM memory.
- explain the differences in the ECM dataflow between the CCC-carbureted and CCC-injected systems.
- explain how to replace an ECM and PROM, and how to service CCC connectors.

When attempting to locate the cause of driveability complaints on General Motors vehicles with the CCC system, there are a few important facts you must remember. *First, always assume that the cause of the problem is not within the CCC system in the first place.* As mentioned in previous chapters, the majority of driveability problems are due to simple things that technicians have dealt with for years, like a defective spark plug, high tension cable, distributor cap, or rotor. Even a simple thing like a leaking or disconnected vacuum hose can cause multiple driveability problems.

Second, if the ECM flashes the CHECK ENGINE light and stores a trouble code, do not assume that the ECM or one of the CCC components is at fault. The real cause of the malfunction may in fact be one of the simple problems listed above or a disconnected, dirty, or corroded connector wiring.

With these facts in mind, let's begin the study of typical diagnostic procedures with some important service tips and the equipment necessary to do the job. Just keep in mind that the following procedures are just samplings. It would be impossible in the space available in this chapter to cover the diagnostic procedures for all model years and system variations.

21-1 GENERAL SERVICE INFORMATION

Before starting any form of system diagnostics on the CCC system, there are a number of service-related tips you should be aware of and follow. These not only will save you time in the long run in locating the cause of the problem but will also prevent the unnecessary replacement or destruction of an otherwise serviceable part.

Service Tips

1. If possible, discuss the problem with the vehicle owner. Try to find out exactly when and under what conditions the malfunction occurs. Also, attempt to determine what types of maintenance have been done recently under the hood or on the CCC system. Pay special attention to any system alterations recommended by service bulletins and to whether the PROM or ECM has been replaced.

2. Test drive the vehicle (with the owner, if possible) to verify the problem.

3. Make an underhood visual inspection. Check all vacuum hoses for pinches, cuts, and connection to their proper fittings. Be sure to inspect hoses that are difficult to see beneath the air cleaner, A/C compressor, alternator, etc. Refer to the emission label for correct hose routing. Inspect all the wiring and connectors within the engine compartment for disconnection, burned or chafed spots, pinched areas, and wires contacting sharp edges or hot exhaust manifolds. Be sure all wire harness grounds at the engine or between the engine, body, and frame are clean and tight. Make sure that all CCC wiring harnesses are away from high voltage or current-carrying wires to prevent electromagnetic interference. Finally, if applicable, check the choke valve for freedom of movement, and make sure it opens and closes.

4. Use electronic and basic test equipment to determine if the condition is the result of defective ignition, emission control, carburetion, or internal engine components.

5. Never install replacement parts by appearance only. Many CCC parts look similar but function differently.

6. Always follow every step in the diagnostic troubleshooting charts.

7. Never use RTV compounds when installing an oxygen sensor, or it will become contaminated and malfunction. Instead, coat the threads of the sensor with an anti-seize compound.

8. Never relocate or alter the mounting of the ECM.

9. The ignition switch must be off when disconnecting or connecting the harness connector to the ECM.

10. Always route two-way radio or mobile phone wires away from the ECM and its wiring harness.

11. Never utilize the ECM case as a ground for other accessories.

12. Do not install a new or remanufactured ECM without verifying whether it has the proper part number and PROM for the vehicle.

13. Make sure the catalytic converter is in place and serviceable. A missing converter upsets exhaust system backpressure, resulting in EGR malfunctions. This can lead to a number of driveability complaints including spark knock. Moreover, the oxygen sensor may run too cool to function properly.

14. Review and follow the general safety precautions found in Chapter 5 of this text.

15. Always use the static protection kit when working on or around the ECM. The function and description of this kit are discussed in Chapter 5 under general safety precautions.

Tools and Equipment

Figure 21-1 illustrates a number of special tools needed to troubleshoot the CCC system. Many of these have already been described in Chapter 5. However, do note the two tools used for removing the weather pack and ECM connector terminals. In addition, the jumper wires shown must have weather pack terminals installed as indicated. During a number of tests, these jumper wires are installed between certain harness connector terminals and those on a given component in order to perform particular electrical tests.

Figure 21-2 shows the special tools needed to test or adjust components of the feedback carburetor. With the exception of the spark tester, dwellmeter, and ISC motor tester, these tools are used to service and adjust the feedback carburetor. The dwellmeter is used on the CCC system to monitor fuel delivery as determined by an ECM output command. The ISC motor tester checks the operation of the motor in either direction plus the condition of the internal switch.

Scan Tool

Beginning with the 1981 model year, one type of CCC diagnosis charts use an ALCL scan tool like a Monitor 2000. This tool plugs into the ALCL connector located below the instrument panel and a power source.

The scan tool permits the technician to check for trouble codes and the data stream from the ECM, such as sensor and switch input. However, this data stream is only updated every 1.25 seconds. This makes the tool less effective than a voltmeter for finding an intermittent problem that lasts less than the 1.25-second period. The scan tool does permit the technician to manipulate wiring harnesses or connectors under the hood while observing the scan readout, as an aid in finding intermittent problems.

The scan tool (from the data stream) also monitors the ECM output command signals. But it is important to understand that although the tool may show that a device has been turned on by the ECM (i.e., TCC, EGR, M/C solenoid, etc.), the indication only represents the command signal to the specific circuit involved. The only way to verify the component's operation is by observation of the device, if possible, or a change in the system that the device affects.

The scan tool is also useful for comparing the data stream from a poorly running engine to that from a known good one. In this way, for example, a sensor that changes value but does not set a code can be detected.

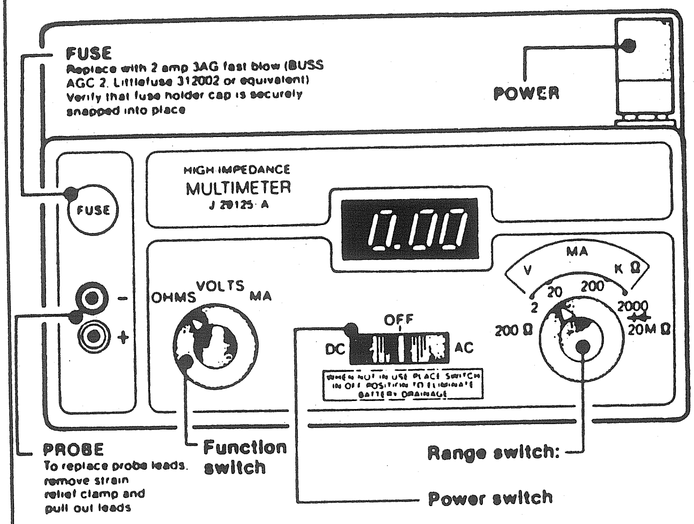
The scan tool can save time in diagnosis and prevent the replacement of good parts. The key to using the tool successfully lies in the technician's understanding of the system being tested and the tool's limitations. Therefore, the technician must read the tool's operating manual to become familiar with it.

Trouble Codes

When a problem develops within the CCC system, the CHECK ENGINE light will come on and a trouble code will set in ECM memory. If the problem is intermittent, the CHECK ENGINE light will go out after 10 seconds when the problem goes away. However, a trouble code will be set in memory until the voltage to the ECM Terminal R is removed. Removing battery voltage to this terminal for 10 seconds clears all stored trouble codes. On most applications, the ECM voltage is supplied from a fuse in the fuse block. If the intermittent problem does not recur for 50 on/off cycles of the ignition switch, then the stored trouble code will be erased from memory.

If the trouble code can be obtained when the CHECK ENGINE light is off and the engine is operating, the code must be evaluated. For example, a determination has to be made regarding whether the problem is intermittent or if the engine has to be operating under certain conditions to turn the light on. Problems indicated by codes 13, 15, 24, 44, and 45 (Fig. 21-3) require engine operation at part throttle for up to five minutes before the light will come on and a code is set.

The diagnostic charts for codes 13, 14, 15, 24, 35, 41, 45, and 55 should be used if any of these codes are obtained with the engine running, even though the CHECK ENGINE light is not on. On the other hand, if any other trouble code is stored with the light out, the diagnostic charts for them cannot be used because the system must have been operating properly at the time the code was set. In other words, the light should have come on at some point if the system did indeed malfunction. In this case, a



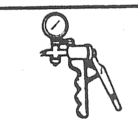
HIGH IMPEDANCE MULTIMETER
J29125-A

VOLTMETER–Voltage Position Measures amount of voltage. Connected parallel to exiting circuit. A digital high impedance voltmeter is used because some circuits require accurate low voltage readings, and some circuits have a very high resistance in the ECM. This meter also accurately measures extremely low current flow. Refer to meter for more information.

- Both function and range switch must be set properly, and the DC or AC position selected. DC is used for most measurements.

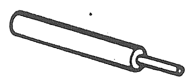
OHMMETER–Resistance Position Measures resistance of circuit directly in ohms. Refer to meter for more information.

- $\boxed{1.}$ display in all ranges indicates open circuit.
- Zero display in all ranges indicates a short circuit.
- Intermittent connection in circuit may be indicated by digital reading that will not stabilize on circuit.
- Range Switch.



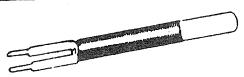
J23738/BT7517

VACUUM PUMP (20 IN. HG. MINIMUM)
Use gage to monitor manifold engine vacuum. Check vacuum sensors, solenoids and valves with hand pump.



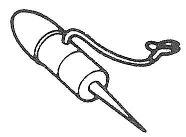
J28742/BT8234-A

WEATHER PACK TERMINAL REMOVER
Used to remove terminals from Weather Pack connectors. Refer to wiring harness service for removal procedure.

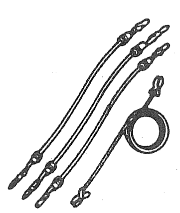


J33095/BT8234-A

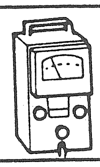
ECM CONNECTOR TERMINAL REMOVER
Use to extract a terminal from connectors at the ECM.



UNPOWERED TEST LIGHT
Used to check wiring for complete circuit. Connect lead wire to good ground. Probe with test prod to connector or component terminal. Bulb will light if voltage is present.

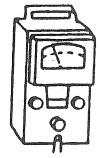
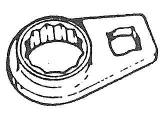
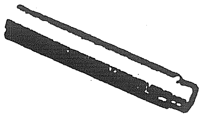
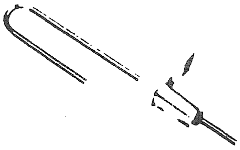
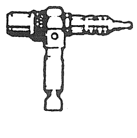
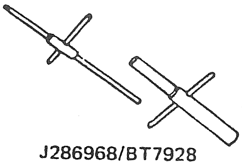
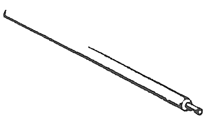
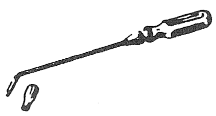


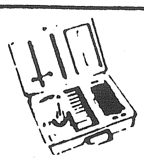
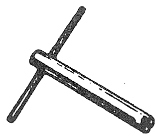
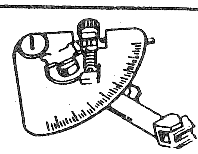
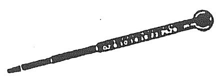
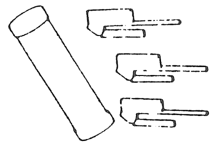
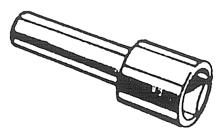
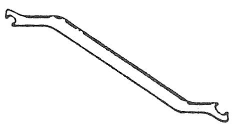
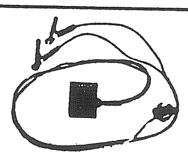
JUMPER WIRES (#16, 18 OR 20 GAGE WIRE)
- Clip jumper wire used to complete a circuit by bypassing an open.
- Set of jumper wires used to insert between Weather Pack connectors to permit access to the connector terminals for circuit checking. Six wires approximately 6" long. Use terminals 12014836 and 12014837. One set - female terminals both ends, one set - male at both ends and four sets - male terminals at one end and female terminals at the opposite end.



TACHOMETER
Use either a crankshaft harmonic balance pickup type or electronic coil trigger signal pickup type

FIGURE 21-1
Special tools used to diagnose the CCC system.
(Courtesy of General Motors Corp.)

	**DWELLMETER** USED TO MONITOR THE FUEL CONTROL DELIVERY DETERMINED BY THE ECM COMMAND. (SET ON 6 CYL. SCALE)
 J29533A/BT8127	**OXYGEN SENSOR WRENCH** USED TO REMOVE OR INSTALL THE OXYGEN SENSOR
 J33815-1/BT8253-A	**M/C SOLENOID GAGING TOOL** USED TO ADJUST THE MIXTURE CONTROL SOLENOID PLUNGER ON E2ME OR E4ME CARBURETOR
 J33815-2/BT8253-A	**AIR BLEED VALVE GAGING TOOL** USED TO ADJUST IDLE AIR BLEED VALVE ON E2ME OR E4ME CARBURETOR
 J26795/BT7220-1	**HEI SPARK TESTER** USE TO CHECK HEI SPARK VOLTAGE.
 J286968/BT7928	**MIXTURE ADJUSTMENT TOOL** USED TO ADJUST LEAN MIXTURE AND RICH MIXTURE STOP SCREWS ON E2SE, E2ME OR E4ME CARBURETOR
 J25322/BT7523	**PUMP LEVER PIN PUNCH** USED TO DRIVE PUMP LEVER PIN INWARD TO ALLOW REMOVAL OF THE PUMP LEVER.
 J22646-02	**CARBURETOR ADJUSTMENT WRENCH** USED TO REMOTE ADJUST IDLE MIXTURE NEEDLE ON THE VEHICLE.

 J9789-C/BT3005	**CARBURETOR GAGE SET** USED TO PERFORM CARBURETOR GAGE AND ANGLE SETTING
 J9789-111/BT8231C	**BENDING TOOL** **(PART OF J9789-C)** USED TO BEND CARBURETOR LINKAGE.
 J26701-A/BT7704	**CHOKE ANGLE GAGE** **(PART OF J9789-C)** USED TO SET CHOKE ANGLE TO ADJUSTMENT SPECIFICATION
 J34935-1/BT4220-A	**CARBURETOR FLOAT LEVEL GAGE** **(PART OF J34935-1)** USED TO CHECK FLOAT LEVEL ON M/C SOLENOID PLUNGER TRAVEL ON E2ME OR E4ME CARBURETOR
 J9789-135/BT8104	**FLOAT LEVEL GAGE SET** USED TO CHECK FLOAT LEVEL ON 2SE OR E2SE CARBURETOR
 J29030-B/BT7610B	**IDLE MIXTURE SOCKET** USED TO ADJUST IDLE MIXTURE NEEDLE ON A E2SE CARBURETOR
 J29607/BT8022	**ISC ADJUSTING WRENCH** USED TO ADJUST ISC PLUNGER TO OBTAIN MAXIMUM SPECIFICATION RPM SPEED.
 J34025/BT8256A	**ISC MOTOR TESTER** USED TO TEST OPERATION OF ISC MOTOR IN EITHER DIRECTION AND CONDITION OF THE INTERNAL SWITCH

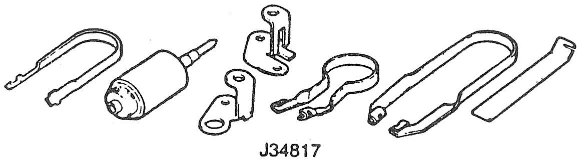
 J34817	**FLOAT POSITIONING TOOL KIT**

FIGURE 21-2
Special tools used to test the ignition and to adjust feedback carburetors. (Courtesy of General Motors Corp.)

TROUBLE CODE 12
No distributor reference pulses to the ECM. This code is not stored in memory and will only flash while the fault is present.
TROUBLE CODE 13
Oxygen Sensor Circuit — The engine must run up to five minutes at part throttle, under road load, before this code will set.
TROUBLE CODE 14
Shorted coolant sensor circuit — The engine must run up to five minutes before this code will set.
TROUBLE CODE 15
Open coolant sensor circuit — The engine must run up to five minutes before this code will set.
TROUBLE CODE 21
Throttle position sensor circuit — The engine must run up to 25 seconds, at specified curb idle speed, before this code will set.
TROUBLE CODE 23
Open or grounded M/C solenoid circuit.
TROUBLE CODE 24
Vehicle speed sensor (VSS) circuit — The car must operate up to five minutes at road speed before this code will set.
TROUBLE CODE 32
Barometric pressure sensor (BARO) circuit low, or altitude compensator low on J-Car.
TROUBLE CODE 34
Manifold absolute pressure (MAP) or vacuum sensor circuit — The engine must run up to five minutes, at specified curb idle speed, before this code will set.
TROUBLE CODE 35
Idle speed control (ISC) switch circuit shorted. (Over 50% throttle for over 2 sec.)
TROUBLE CODE 41
No distributor reference pulses to the ECM at specified engine vacuum. This code will store in memory.
TROUBLE CODE 42
Electronic spark timing (EST) bypass circuit or EST circuit grounded or open.
TROUBLE CODE 43
ESC retard signal for too long; causes a retard in EST signal.
TROUBLE CODE 44
Lean exhaust indication — The engine must run up to five minutes, in closed loop, at part throttle and road load before this code will set.
TROUBLE CODES 44 & 55
(At same time) — Faulty oxygen sensor circuit.
TROUBLE CODE 45
Rich exhaust indication — The engine must run up to five minutes, in closed loop, at part throttle and road load before this code will set.
TROUBLE CODE 51
Faulty calibration unit (PROM) or installation. It takes up to 30 seconds before this code will set.
TROUBLE CODE 54
Shorted M/C solenoid circuit and/or faulty ECM.
TROUBLE CODE 55
Grounded Voltage ref. (terminal "21"), faulty oxygen sensor or ECM.

FIGURE 21-3
CCC trouble codes.

physical inspection of the circuit indicated by the code should be made. It should be inspected for poor connections, frayed wires, etc. In addition, a system performance check should be made as explained in the next section.

ALCL Connector

Before performing any diagnosis on the CCC system itself, you must be familiar with the location and function of the *assembly line communication link (ALCL) connector*, which on later vehicles is called the assembly line data link (ALDL) connector. This unit is a 4-, 5-, or 12-terminal connector that is located under the dash, normally on the driver's side (Fig. 21-4).

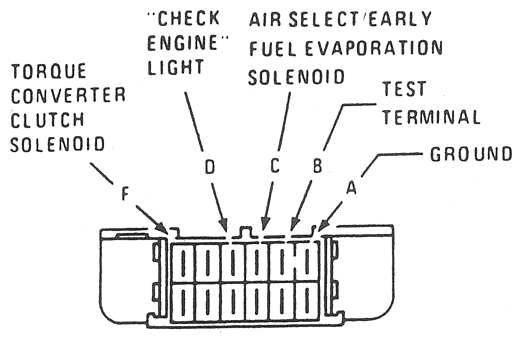


FIGURE 21-4
ALCL connector. (Courtesy of General Motors Corp.)

The ALCL connector has several functions. It is used first at the assembly plant to connect a computer into the system in order to verify its operation before shipping the vehicle. Moreover, the connector is utilized in the field to obtain service codes by activating the built-in self-diagnostic system. This is accomplished by grounding its ALCL test terminal. A scan tool plugged into the connector will not only display the service codes but the data stream as well.

There is one important thing to remember about the ALCL connector. That is, the number and arrangement of terminals are different between model years. Therefore, before attempting to ground the test terminal, verify its exact location in the service manual. Finally, the 1979 and early 1980 systems did not have an ALCL connector. Instead, there was a single-lead, green connector hanging near the ECM. By grounding this lead, any stored codes could be read by counting the flashes of the CHECK ENGINE light.

With the ALCL test terminal grounded, the ignition switch on, and the engine not running, the ECM self-diagnostic system will cause the CHECK ENGINE light to flash a 12 or any problem code, direct a 30-degree dwell signal to the M/C solenoid, energize all ECM-controlled output solenoids, and pulse the ISC motor in and out.

However, if the test terminal is grounded with the engine operating, the ECM self-diagnostic system will not set any trouble codes; take out the open loop timer and the start-up and blended enrichment modes; direct a 30-degree dwell signal to the M/C solenoid whenever the system is in open loop, that is, if it is not operating in the enrichment mode; and cause EST to be set at a fixed amount of spark advance. The latter is used for checking EST operation.

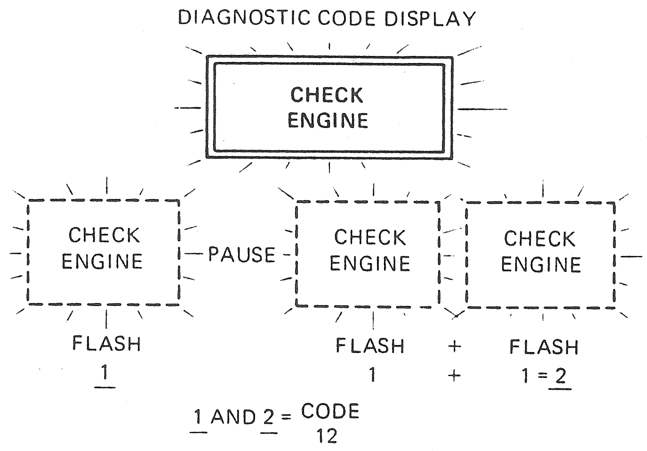


FIGURE 21-5
CHECK ENGINE light and trouble codes. (Courtesy of General Motors Corp.)

CHECK ENGINE Light

As mentioned, the CCC self-diagnostic system will catch and store the problems that are most likely to occur. In order to warn the driver that a problem exists, the ECM flashes a CHECK ENGINE light on the instrument panel (Fig. 21-5).

As a bulb and system check, the light will come on whenever the driver turns the ignition on with the engine not operating. When the engine is started, the light remains on momentarily and then goes off. However, if the light flashes or stays on, the self-diagnostic system has detected a fault.

The technician then can use the CHECK ENGINE light to read any problem codes stored in memory by grounding the test terminal on the ALCL connector after turning on the ignition switch. If the self-diagnostic system is functioning and there are no stored problem codes, the light will flash a Code 12. Code 12 indicates the ECM is not receiving a REF signal from the distributor. A Code 12 consists of one flash, followed by a short pause, then two flashes in quick succession. After a longer pause, the code will repeat two more times.

If another code appears, this indicates a problem in a given circuit (see Fig. 21-3). This code will also flash three times. In addition, if more than one fault has been detected, each code will flash three times in numeric order (i.e., the lowest number code first).

As mentioned, a trouble code indicates a particular problem. If a trouble code like 14 appears, for example, there is a problem within the coolant sensor circuit. The problem could be the sensor, connector, harness, or the ECM. The procedure for finding the cause of the problem is found in the diagnostic chart provided for each code. Finally, since the system self-diagnostics do not detect all possible problems, the absence of a code does not mean that a fault within the CCC is not present. In this case, a system performance check should be made, as explained in the next section.

21-2 CCC-CARBURETED SYSTEM DIAGNOSIS

There are several ways to begin the actual diagnosis of any driveability complaint. The method used depends on whether or not the driver saw the CHECK ENGINE light. If the light never came on, in many cases, the problem is not within the CCC system itself. In this situation, always carry out the underhood inspection first and then a complete performance analysis of the engine and its support systems.

If the CHECK ENGINE light did come on, perform the underhood inspection first. Then perform the diagnostic circuit check.

Diagnostic Circuit Check

The *diagnostic circuit check* is the first actual test of any system controlled by the ECM (Fig. 21-6). This check, as you can see in the illustration, always leads to the system performance check.

There are three purposes of the diagnostic circuit check:

1. To make sure the CHECK ENGINE light operates.

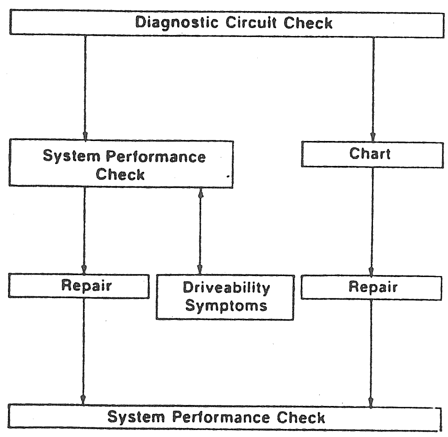


FIGURE 21-6
Diagnostic procedure. (Courtesy of General Motors Corp.)

2. To check if the ECM is functioning and can recognize a problem.

3. To determine if any codes are stored in memory. If codes are stored, the check indicates whether the problem is intermittent or not.

To perform the diagnostic circuit check without a scan tool, do the following:

1. With the engine not running, turn the ignition key on. The CHECK ENGINE light should come on steady (Fig. 21-7).

2. Ground the ALCL test terminals and note the CHECK ENGINE light. It should flash a 12 or any stored trouble code. The light must go completely on and off to indicate a proper code. If the light just goes from bright to dim, this is not considered a code. Record any problem codes other than 12.

3. Turn the ignition switch off and unground the ALCL test terminal. Clear the long-term memory. Next, operate the engine for two minutes at curb idle and note if the CHECK ENGINE light comes on. This step determines if the problems that caused previously stored codes are still present, or if they were intermittent and are no longer there. Shut the engine off.

4. If the light did come on, turn the ignition switch on and ground the ALCL test terminal. Record all codes received. Proceed to the applicable trouble code chart.

5. If the light remained off, the problem is either intermittent, or it has a code that cannot be set in memory in two minutes. For codes that are not set in memory within two minutes, follow the procedure shown in Fig. 21-7 to determine if they are intermittent or not. If no codes other than 12 were noted during the circuit check, proceed with the system performance test.

You can also use a scan tool when performing the diagnostic circuit check. To do so, first complete Steps 1 and 2 in the above procedure. Then begin with Step 3 as follows (Fig. 21-8):

3. Unground the test terminal and plug the scan tool connector into the ALCL. Also, plug its power connector into the cigarette lighter. Note any codes displayed. If the scan tool does not operate, check it on another vehicle. If it operates then, check the socket of the cigarette lighter for proper voltage and a good ground.

4. If codes are displayed, use the applicable trouble code chart to locate the cause of the problem. If no codes are displayed at this point, the problem was intermittent or nonexistent. In this situation, proceed with the system performance check.

System Performance Check

The *system performance check* verifies that the CCC system is functioning. Specifically, the procedure checks the ability of the M/C solenoid to change the air/fuel ratio delivered to the engine by the carburetor's main and idle systems. This check should be performed whenever the suspected cause of a driveability complaint is in the CCC system or after work on the system has been completed.

To perform this check, follow the steps outlined in Fig. 21-9 and the following explanations:

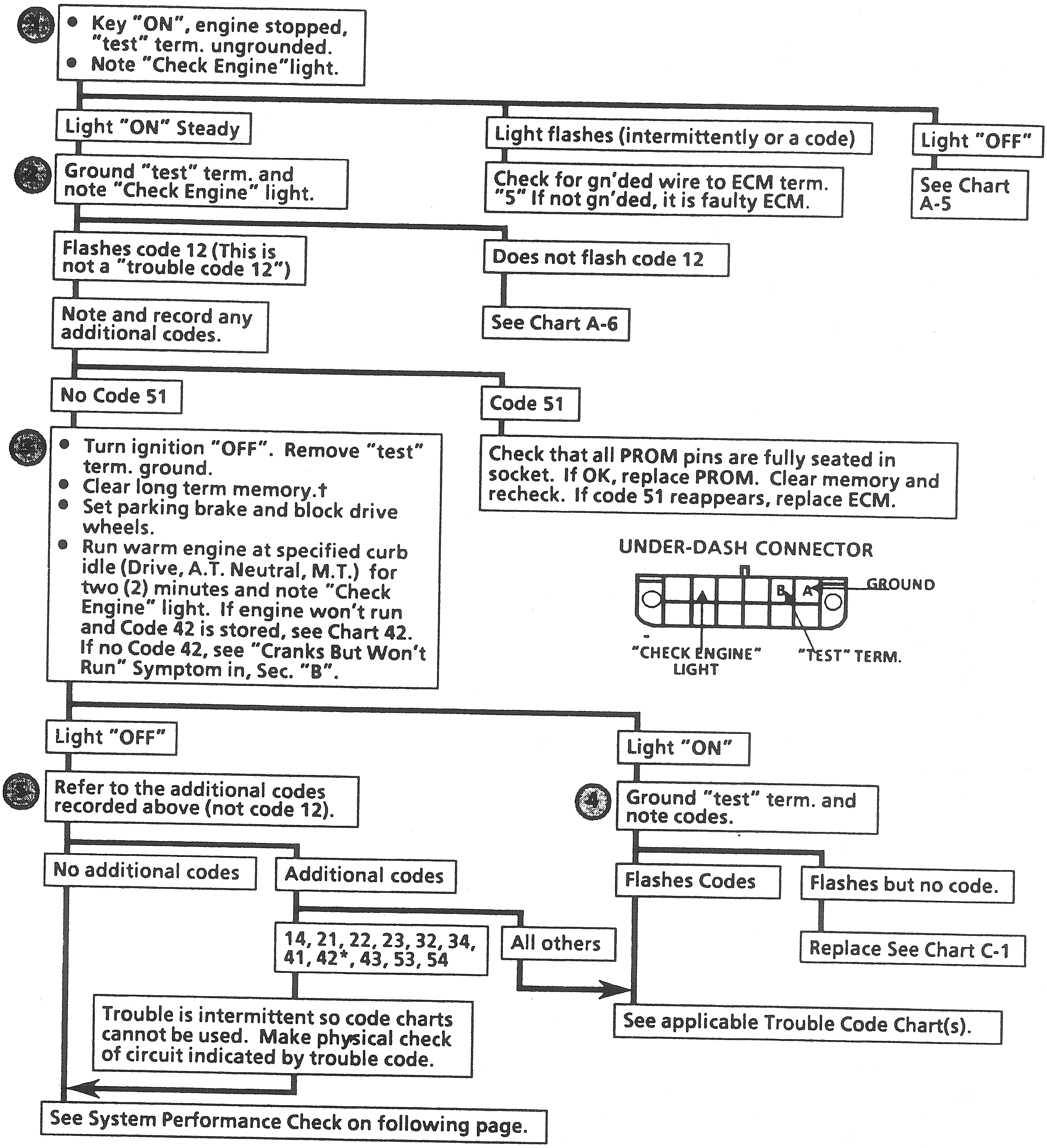
- Disconnecting the M/C solenoid connector during Step 1 makes the carburetor operate full-rich, and reconnecting it with the dwell lead still grounded makes the unit function full-lean. The normal response is that the rpm drops as the M/C solenoid is reconnected—usually 400 rpm to 1,000 rpm, but no less than 300 rpm.

Note: The dwell is located in the M/C solenoid harness.

- Step 1A is next if the rpm drop in Step 1 is less than 300 rpm or if the rpm increases. This step may determine that the M/C solenoid is polarity sensitive. If it is, the solenoid will not pull its plunger down fully until the polarity is reversed. If plugging the PCV, purge, or bowl vent vacuum hose causes the rpm to drop over 300 rpm, the affected hose leads to the source of the richness problem. If rpm increases as the M/C solenoid connector is plugged in, this indicates the main system is operating extremely rich.

- Step 2 checks the M/C solenoid control of the idle circuit.

- In Step 2A, the dwell meter indicates a full-rich command to the M/C solenoid. This can be caused by a lean engine operating condition, a grounded oxygen sensor wire or defective sensor, an opening in the wire from ECM Terminal 14 to ground, an opening in the wire to ECM Terminal 22, or an open in the coolant sensor circuit (see Chart A-1, Fig. 21-10).



† To clear codes, remove power to 'R' term. of ECM for 10 sec. by removing ECM connector with ignition "OFF", or ECM/BAT fuse, or disconnect ECM power feed at battery. Verify codes have been cleared. The System Performance Check should be performed after any repairs to the System have been made.

* It is possible to set a false Code 42 on starting, but the "Check Engine" light will not be "ON". No corrective action is necessary.

FIGURE 21-7
Diagnostic circuit check. (Courtesy of General Motors Corp.)

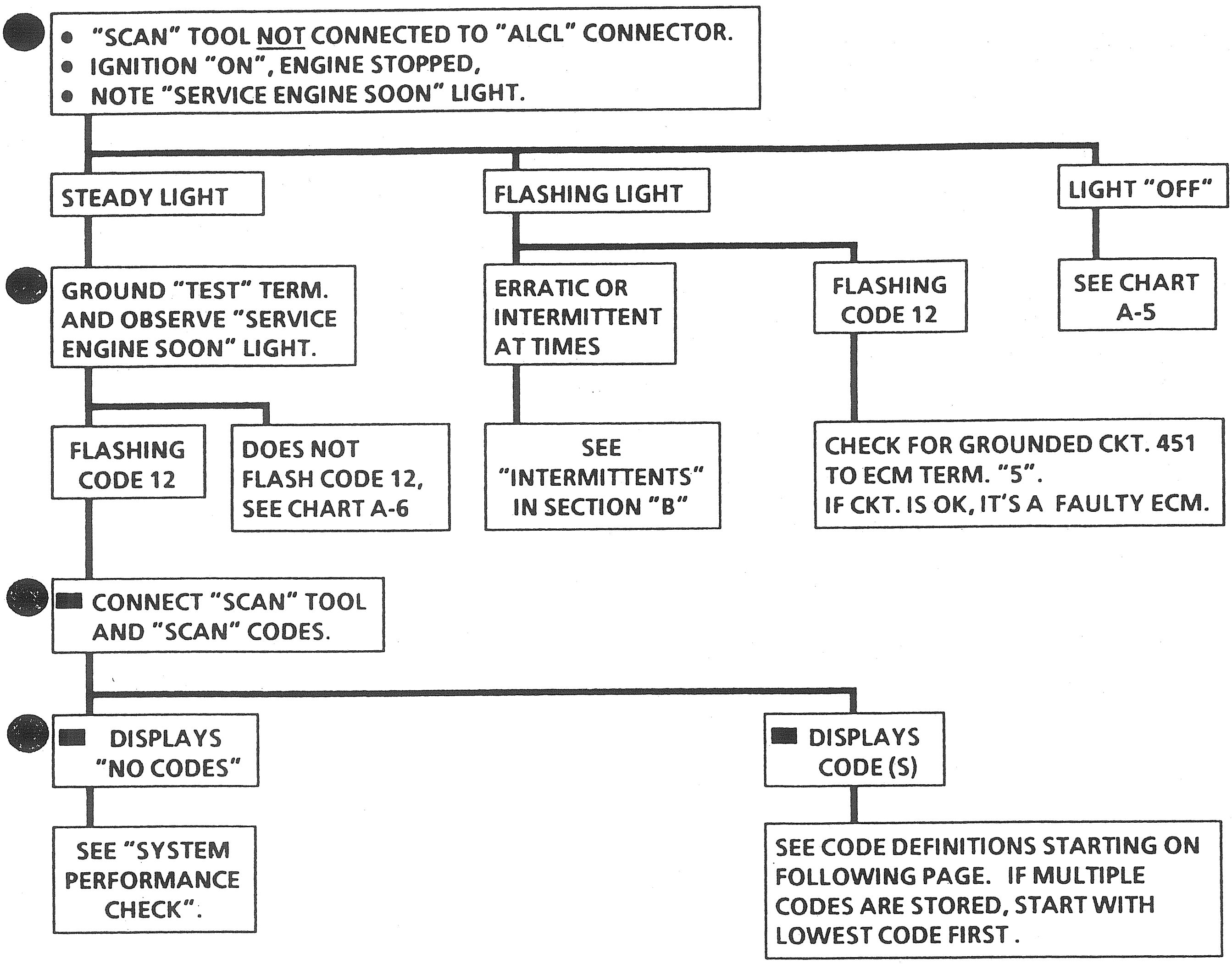


FIGURE 21-8
Diagnostic circuit check with a scan tool. (Courtesy of General Motors Corp.)

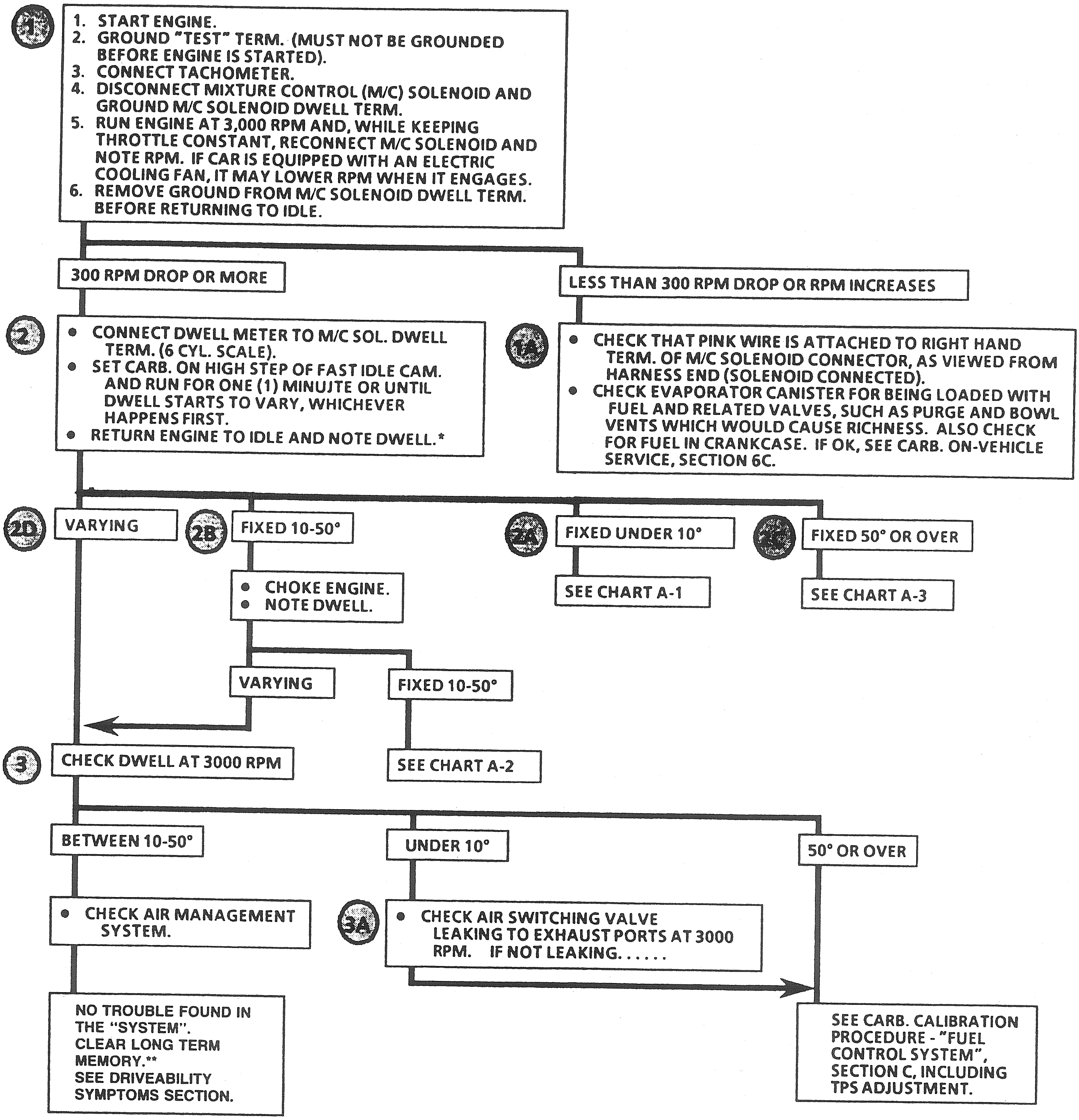
• In Step 2B, the dwell meter is showing an open loop condition. This can result from an opening in the oxygen sensor circuit or a defective sensor, an opening in the coolant temperature sensor circuit, or an opening in the wire from the ECM Terminal 14 to ground (see Chart A-2, Fig. 21-11).

• In Step 2C, the dwell meter indicates a full-lean command to the M/C solenoid. This can be caused by a rich engine operating condition resulting from the wires to the M/C solenoid being reversed, a leaking bowl vent valve, excessive fuel within the carbon canister, excessive fuel in the engine oil, faulty carburetor calibration or a faulty unit itself, or a silicone-contaminated oxygen sensor (see Chart A-3, Fig. 21-12).

• The dwell meter in Step 2D shows a normal reading with the system operating in closed loop. The dwell should be between 10 degrees and 50 degrees, but varying. Running the engine for one minute will ensure that the oxygen sensor is at normal operating temperature.

• Step 3 checks for the proper control by the ECM and M/C solenoid of the main metering system of the carburetor. In this situation, the rpm must be at least 3,000 to make sure the main metering system is in operation.

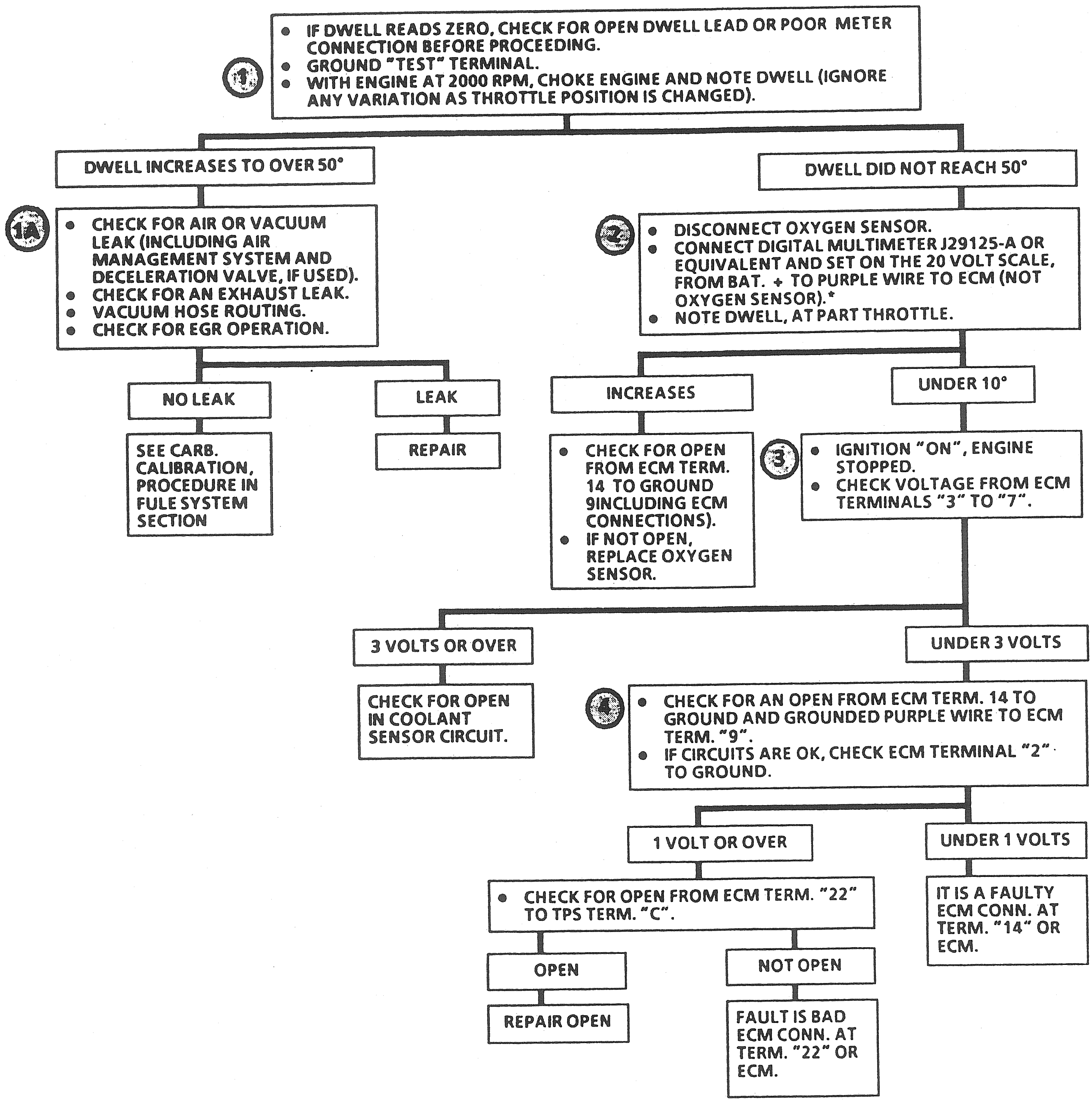
• In Step 3A, a missing O-ring between the switching valve solenoid and the valve, or a faulty valve, may cause air leakage into the exhaust ports only at higher rpm.



* OXYGEN SENSORS MAY COOL OFF AT IDLE AND THE DWELL CHANGE FROM VARYING TO FIXED. IF THIS HAPPENS, RUNNING THE ENGINE AT FAST IDLE WILL WARM IT UP AGAIN.

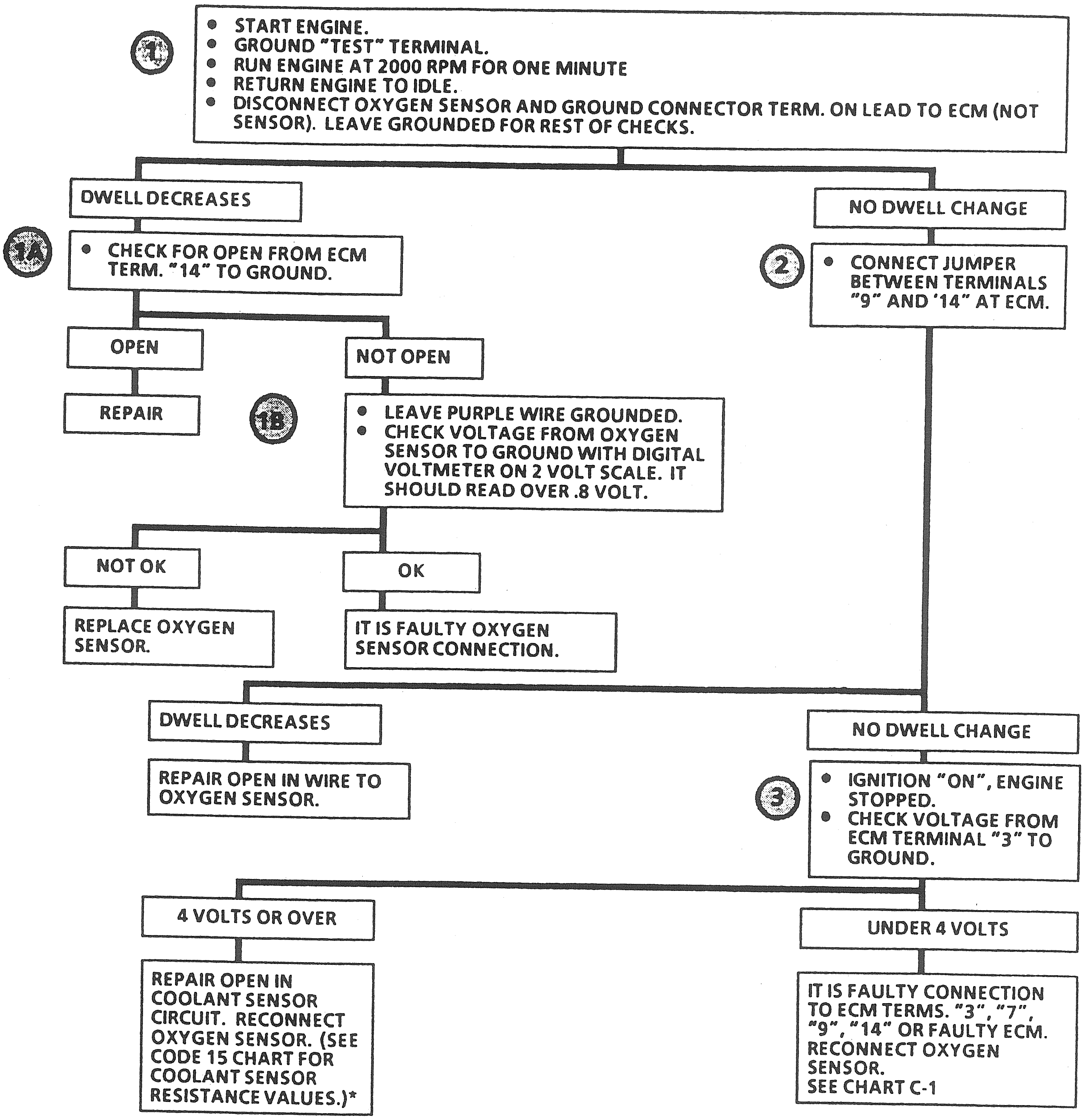
** SEE CODE(S) CLEARING PROCEDURE.

FIGURE 21-9
System performance check.
(Courtesy of General Motors Corp.)



* DO NOT USE AN ORDINARY VOLTMETER OR JUMPER IN PLACE OF DIGITAL VOLTMETER, BECAUSE THEY HAVE TOO LITTLE RESISTANCE. A VOLTAGE SOURCE OF 1.0V TO 1.7V (SUCH AS A FLASHLIGHT BATTERY) CAN BE CONNECTED WITH THE POSITIVE TERMINAL TO THE PURPLE WIRE AND THE NEGATIVE TERMINAL TO GROUND AS A JUMPER. IF THE POLARITY IS REVERSED, IT WON'T WORK.

FIGURE 21-10
Chart A-1. (Courtesy of General Motors Corp.)



* CHECKING COOLANT SENSOR RESISTANCE MAY REQUIRE USE OF CONNECTOR AND WIRE ASSEMBLY NO. 12026621 FOR ACCESSIBILITY.

FIGURE 21-11
Chart A-2. (Courtesy of General Motors Corp.)

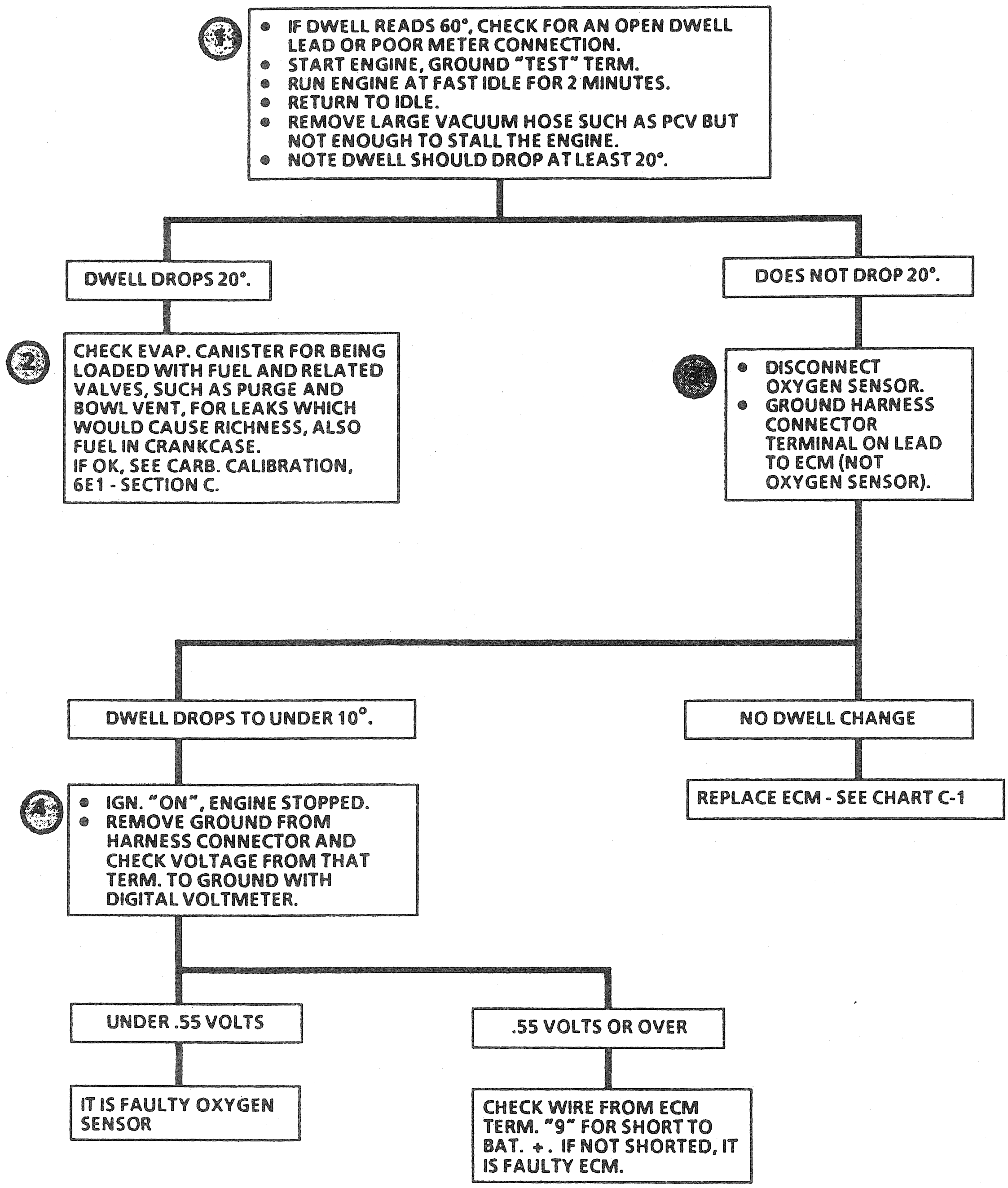


FIGURE 21-12
Chart A-3. (Courtesy of General Motors Corp.)

21-3 DIAGNOSING SYMPTOMS OF DRIVEABILITY COMPLAINTS

Now that you know the purpose of and how to perform the diagnostic circuit and system performance checks, let's begin examining the process of locating the causes of driveability complaints. In the process covered in this section, the diagnosis will be based on problem symptoms provided by the driver. There will be no trouble codes stored in ECM memory.

Before Starting

Before starting the actual diagnosis of a given symptom, the following are three basis steps to carry out first:

1. Perform a careful visual inspection under the hood. The importance of this step cannot be stressed strongly enough. It can lead to correcting a problem without any additional checks and thus save valuable time.

2. Perform a diagnostic circuit check. This verifies that the CHECK ENGINE light is functioning and whether there are stored trouble codes.

3. Perform a system performance check to make sure the fuel control system is functioning properly.

Intermittents

As mentioned, a number of driveability complaints will be intermittent and, therefore, may or may not turn on the ENGINE CHECK light or set a code in ECM memory. The problem causing the symptom you are diagnosing may fall into this category. In this situation, the fault must be present in order to locate its cause. You cannot use the trouble code charts to locate an intermittent problem; this may result in the replacement of serviceable parts.

The majority of intermittents are caused by problems in electrical connections, wiring, or components; these types of faults require careful inspection to locate. Listed below are some of the most common problem areas and what should be done to correct the located faults.

- Poor mating of connector halves or terminals not full seated in the connector body.

- Improperly formed or damaged terminals. All the connector terminals in a problem circuit must be carefully reformed to increase their contact tension.

- Poor terminal-to-wire connection. This requires removing the terminal from the connector body for further checking and repair.

Note: If a visual check does not pinpoint the cause of the problem within the connectors or wiring, the vehicle should be driven with a voltmeter connected to the suspected circuit. An abnormal volt reading as the problem occurs indicates it is still within that circuit.

- Open ignition coil ground and arcing at spark plugs or high tension cables.

- CHECK ENGINE light wire to the ECM shorted to ground.

- Diagnostic test terminal wire to ECM shorted to ground.

- Poor or no ground for ECU Terminals A and U.

- Loss of trouble code memory. To check for this problem, ground the dwell lead for ten seconds with the ALCL test terminal ungrounded and the engine operating. A Code 23 now should be stored. If not, the ECM is most likely at fault.

- System interference due to a faulty relay, ECM-operated solenoid, or switch. System interference will create a sharp electrical surge in the system that will occur when the faulty component is operated. In this case, the suspected component has to be checked following the procedure outlined in the appropriate service manual.

- Incorrect installation of electrical accessories such as lights or a two-way radio.

- EST wires too close to spark plug and distributor wiring, coil, distributor housing, or alternator.

- Wire from ECM to Terminal 13 to the distributor grounded poorly.

- Open diode or resistor across the A/C compressor clutch.

Now that you understand the three beginning diagnostic steps and the facts on locating intermittent problems, let's look at a few symptoms of common driveability problems and how to find their causes. The two that will be covered are for an engine that starts hard when cold and for an engine that misses.

Engine Hard to Start When Cold. An engine that is hard to start when cold cranks over okay but does not start for a long time. It does, however, eventually run. To locate the cause of the problem, do the following:

1. Make sure the driver is using the correct starting procedure as outlined in the owner's manual.
2. Perform the three basic "before starting" steps outlined above. If everything checks out satisfactory, move to Step 3.
3. Remove the air cleaner and check the choke valve, throttle, and fast-idle cam for sticking. Clean or replace any malfunctioning parts.
4. Check the operation of the choke and vacuum brake, and adjust as necessary. The choke should be closed when cold.
5. Start and warm up the engine. Visually check the choke and vacuum brake operation.
6. Check the float level using an external float gauge. Adjust it as necessary.
7. Check the carburetor fuel inlet filter. Replace it as necessary.
8. Inspect the air filter element. Replace it as necessary, and reinstall the air cleaner. Make sure you install all the disconnected vacuum hoses over their respective fittings.
9. Check the ignition primary and secondary circuits with an oscilloscope. Replace worn or defective components as needed.
10. Check the distributor for a worn shaft; bare or shorted wires; pickup coil resistance; tightness of connections; and moisture, cracks, or presence of carbon runners in the distributor cap or on the rotor.
11. Check ignition timing per the Vehicle Emission Control Information label.
12. Verify the engine has the correct viscosity oil in the crankcase.
13. Check the fuel pump volume, pressure, and vacuum.

Engine Misfires. An engine misfire appears as a pulsation or jerking that is more pronounced usually as engine load increases. The exhaust may also have a steady spitting sound at idle or low speed. Moreover, the symptom may only occur when the TCC is applied, but this does not mean there is a TCC malfunction. To determine the cause of this symptom, do the following:

1. Perform the three basic diagnostic steps.
2. Check the operation of the primary and secondary ignition system with an oscilloscope. Replace any defective parts.
3. Remove the distributor cap. Inspect for a poor ground on the integral ignition coil.
4. Visually inspect the distributor cap and rotor for moisture, dust, cracks, and carbon runners. Replace any defective parts and reinstall the cap.
5. With the engine running, spray the cap and plug wires with a fine water mist to check for shorts.
6. Check the resistance of the pickup coil within the distributor, and inspect its connections at the module. Replace the pickup coil if it is shorted or grounded.
7. Remove the rocker arm covers. Check for bent pushrods, worn rocker arms, broken valve springs, or worn camshaft lobes. Make repairs as necessary.
8. Check the exhaust for restrictions.

21-4 DIAGNOSING DRIVEABILITY PROBLEMS WITH TROUBLE CODES

The next procedure should be followed if the ENGINE CHECK light comes on. In this situation, the driver will most often also complain of some type of driveability problem. However, this is not always the case.

In either case, you must do the following to locate the problem:

1. Perform an underhood visual inspection, and correct any problems encountered.
2. Perform the diagnostic circuit check, and record any trouble codes stored in memory (see Fig. 21-1).
3. If there were no apparent faults discovered in Step 1, use the appropriate trouble code charts to locate the fault.

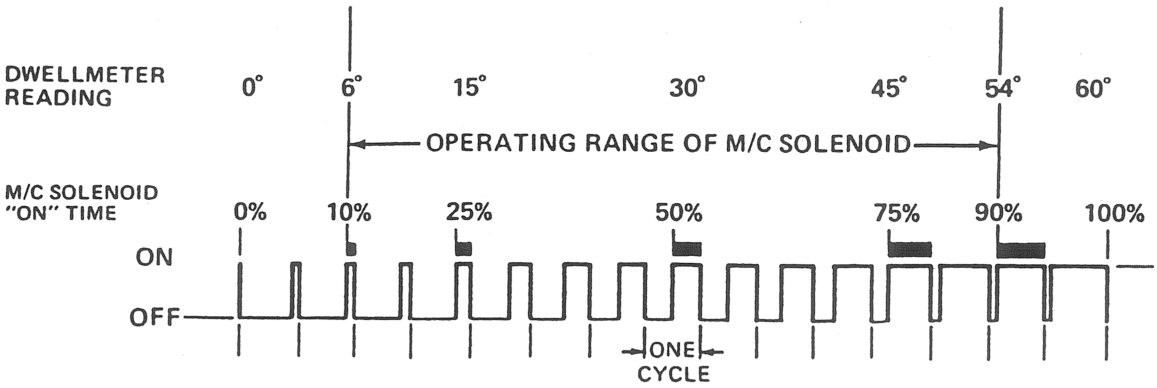


FIGURE 21-16
Interpretation of dwellmeter readings. (Courtesy of General Motors Corp.)

riod of time the M/C solenoid is energized (Fig. 21-16), for diagnositc purposes, in degrees of dwell. A scanner will show the amount of dwell during the various operating phases as part of the ECM data stream.

The dwellmeter, when connected to the M/C harness test connector, also translates the solenoid's energized periods into degrees for underhood diagnosis. For this purpose, the six-cylinder (0-degree to 60-degree) scale on the meter is used. In this situation, the degree scale on the meter indicates percent of solenoid on-time instead of degrees of ignition dwell, which refers to the build-up time of the ignition primary coil circuit.

For example, a dwell reading of 54 degrees means the M/C solenoid provides a lean air/fuel mixture because it is energized 90 percent of the time (see Fig. 21-16). A dwell reading of 6 degrees means that the M/C solenoid is providing a rich mixture because it is only energized 10 percent of the time.

The ideal mixture is shown on the dwellmeter when the needle varies or swings back and forth, between 10 degrees and 50 degrees. The amount the needle moves does not matter, only the fact that it does move. The varying needle movement represents the dwell changes made by the ECM in response to signals from the oxygen sensor.

Integrator and Block Learn Functions and Values

The ECM functions that control the air/fuel ratio of fuel injected engines by altering the injector pulse width are known as integrator and block learn functions. The numerical values for the integrator and block learn functions serve the same diagnosis function as M/C solenoid dwell does on carbureted engines (Fig. 21-17). Moreover, these values can also be read as part of the ECM data stream with a scanner attached to the ALCL/ALDL connector.

The *integrator function* is a means of temporarily changing the air/fuel ratio only in the closed loop mode of ECM operation. The integrator monitors the oxygen sensor input signal and then leans out or richens the air/fuel mixture accordingly.

As mentioned, integrator values are monitored with a scanner and are seen as a number between 0 and 255, with an average of 128. When the integrator value is 128, this indicates a neutral condition, meaning the oxygen sensor is monitoring the results of a 14.7:1 air/fuel mixture being burned in the engine cylinders. This 128 integrator value corresponds to a 30-degree dwell reading on the carbureted system (see Fig. 21-17).

Although the integrator ECM function can alter the air/fuel ratio over a wide range of engine operating conditions, its correction is only temporary. Consequently, the ECM has another function called *block learn*. This function cannot make as much air/fuel ratio correction as the integrator, but what change it does make lasts for a longer period of time.

The block learn function gets it name from the fact that the operating range data of the engine for any combination of rpm and load conditions are divided and stored into 16 cells or blocks. Each one of these blocks will then provide a given amount of fuel delivery. As the engine operating range enters the perimeters of a given block, the actual fuel delivery is based on the value stored in its memory.

Again, like the integrator function, block values represent the on-time (pulse width) of the injectors. The number 128 represents no correction to the value that is stored in a given block (Fig. 21-18).

As the integrator value increases or decreases,

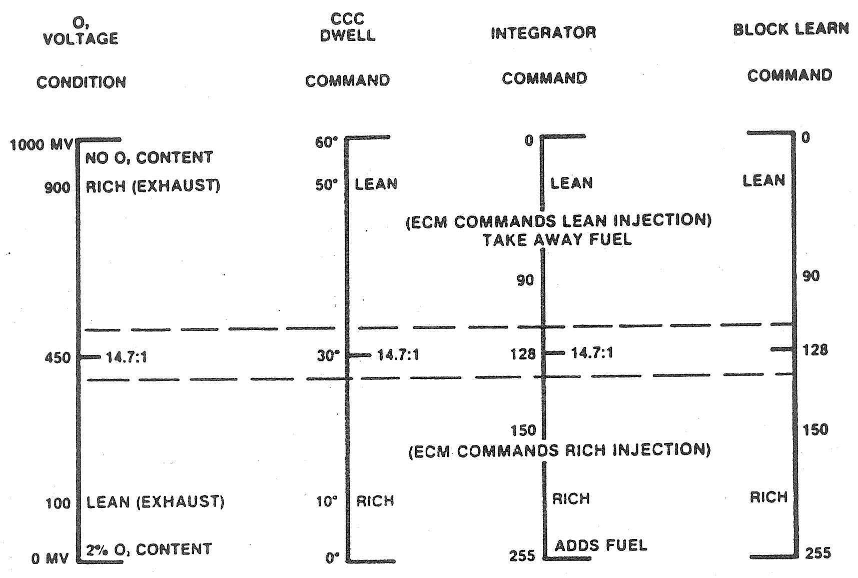


FIGURE 21-17
Relationship among dwell, integrator, and block learn values. (Courtesy of General Motors Corp.)

the block learn function is watching and will make a correction in the same direction, up or down. As the block learn function makes a correction, the integrator also makes a correction until its value returns to 128; that is, if the block learn is maintaining an air/fuel ratio of 14.7:1.

The block learn function operates on two types of memory: nonvolatile memory that retains its value in the cells, even when the ignition switch is turned off; and volatile memory that loses its value when the ignition switch is turned off. In the former case, each time the engine starts, the block learn function begins at 128 in each cell. Each cell then corrects from there as necessary to make the oxygen sensor see the results of a 14.7:1 air/fuel ratio.

Both the integrator and block learn functions have limits that vary with each engine design. If, for example, the mixture is off enough so that block

These readings show that all cells are running at design air fuel ratios of 14.7:1 in all RPM and engine load conditions.

LOAD				
	128	128	128	128
	128	128	128	128
	128	128	128	128
	128	128	128	128
	RPM			

These readings are examples of what may actually be seen when the ECM is compensating for a slightly lean exhaust.

LOAD				
	128	130	128	129
	129	130	130	131
	133	136	129	128
	135	132	129	130
	RPM			

These readings are examples of what may actually be seen when the ECM is compensating for a slightly rich exhaust.

LOAD				
	121	124	128	128
	119	120	119	121
	115	117	116	121
	122	119	126	120
	RPM			

FIGURE 21-18
Block learn data. (Courtesy of General Motors Corp.)

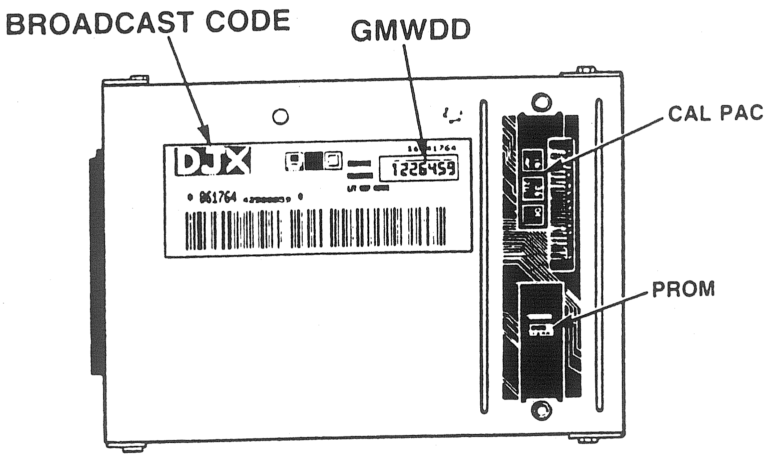


FIGURE 21-19
ECM identification. (Courtesy of General Motors Corp.)

learn reaches the limit of its control and still cannot correct the condition, the integrator would do likewise. In this situation, the engine would then begin to run poorly.

21-7 ECM OR PROM REPLACEMENT AND WEATHER-PACK CONNECTOR SERVICE

ECM Identification

When replacing the ECM, it is a must that the correct replacement be used. The only way to determine the proper unit to install is through its service number. The service number has seven digits and is found on the ECM identification label. Figure 21-19 illustrates a typical ECM identification label. The eight-digit number in the upper-right corner of the identification label is the Delco Electronics Parts Number. The seven-digit number is the GMWDD parts service number. The CAL PACK and PROM will also have eight-digit identification numbers.

ECM Replacement

Before attempting to replace a defective ECM, there are four important facts to remember. First, make sure the replacement ECM has the same service number. Second, transfer the Broadcast Code and production number to the identification label of the replacement ECM. This will provide positive identification of ECM parts throughout the service life of the vehicle. Third, to prevent damage to the ECM, turn the ignition switch off when disconnecting or reconnecting power to the ECM. Fourth, use the static protection kit to prevent damage to the ECM or its components.

The actual procedure for removing and replacing the ECM is somewhat different among model years. For this reason, check the appropriate service manual for the exact procedure to follow before beginning. Figure 21-20 illustrates a typical procedure used on a TBI system with a two-board ECM.

PROM Replacement

There are also a number of facts to remember before attempting to replace a PROM within the ECM. First, to prevent damage to the ECM, turn the ignition switch off when disconnecting or reconnecting power to the ECM. Second, use the static protection kit to prevent damage to the ECM or its components. Third, make sure the replacement PROM has the same service number as the original. Fourth, use a PROM removal tool when taking the unit out of the ECM. Fifth, make sure the PROM is installed into its correct position in the carrier before plugging it into the ECM. If the position of the PROM is reversed in the carrier, the PROM will be destroyed when power is applied to the ECM. Sixth, never touch a PROM pin when removing or installing it into the carrier. A static charge from your body can ruin the PROM.

As in the case of the ECM, there are a variety of procedures for replacing a PROM, depending on the model year of the vehicle. For this reason, always check the service manual for the vehicle to determine the exact procedure to follow. Figure 21-21 shows a typical PROM replacement procedure on a TBI system with a three-board ECM.

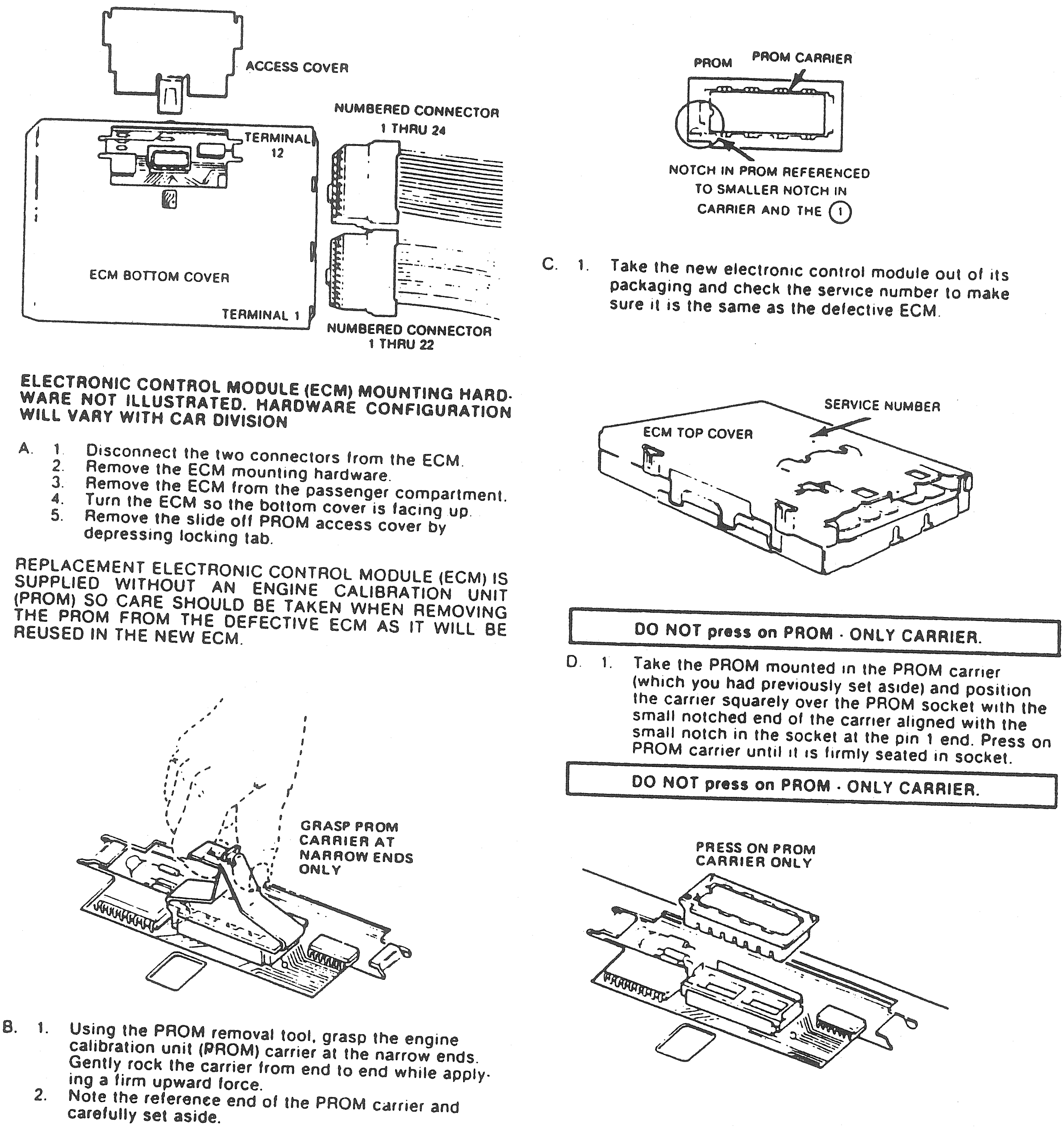


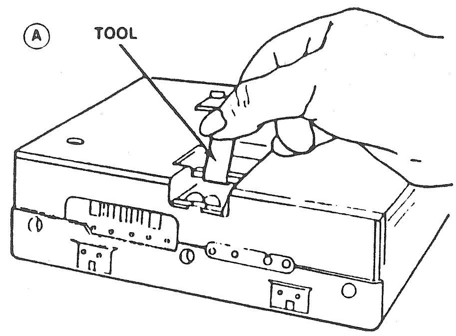
FIGURE 21-20
Typical ECM replacement. (Courtesy of General Motors Corp.)

Weather-Pack Connector Service

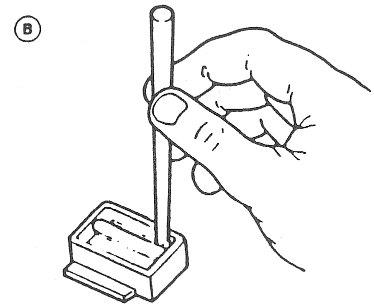
All CCC system wiring terminals within the engine compartment are environmentally protected by special Weather-Pack connectors (Fig. 21-22). The reasons for using this type of connection are the low voltage and current levels within the system and the environment to which the connectors are exposed.

Within the CCC system, the voltage runs as low as 500 millivolts at oxygen sensor connections to five volts at reference voltage connections. Moreover, in nearly all cases, the current flow is below 250 milliamperes.

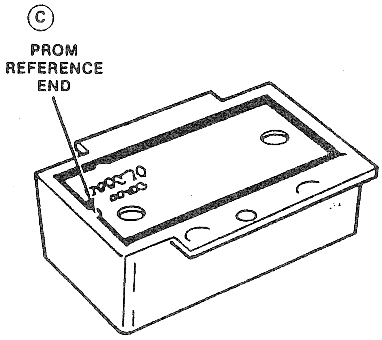
The Weather-Pack connectors protect the wiring terminals from the harsh corrosive engine compartment environment. This is very important since the voltage and current levels are too low to break down any oxidation growth or oil film that forms on



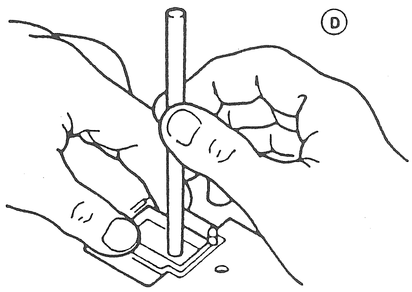
1. Grasp the PROM carrier with the PROM removal tool.
2. Gently rock the carrier from side to side while applying a firm upward force.
3. Remove PROM and carrier.



1. Take the PROM mounted in the carrier and turn it upside down on a flat surface so pins are sticking up.
2. Using a narrow blunt tool, press down on the body of the PROM on both sides of the retainer bar so the top of the PROM is flush with the top of the carrier.



1. Make certain the PROM is oriented in its carrier as shown:



1. Position the PROM carrier squarely over the PROM socket as shown.
2. Press down firmly on the top of the carrier.
3. While firmly holding the carrier down, take a narrow blunt tool and press down on the body of the PROM. Alternately pressing on either end will help seat the PROM securely.

FIGURE 21-21
Typical PROM replacement. (Courtesy of General Motors Corp.)

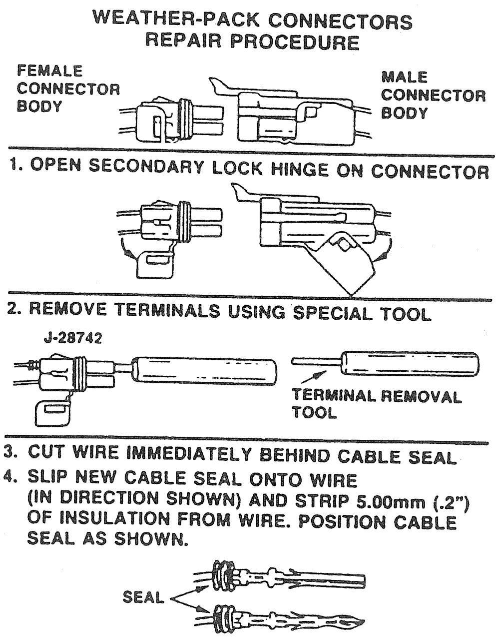


FIGURE 21-22
Weather-Pack terminal service. (Courtesy of General Motors Corp.)

the terminals.

When servicing Weather-Pack connectors, a special tool is necessary (see Fig. 21-22). The tool is used to remove the pin and sleeve assemblies. If removal is attempted with an ordinary pick, the terminal will most likely be bent or deformed. Unlike the standard blade terminals, Weather-Pack units cannot be straightened once they are bent or deformed.

When reinstalling a terminal within the Weather-Pack connector, make sure it is fully seated and its sealing ring is in place. The hinge-type flap on the terminal acts as a back-up, or secondary locking feature for the terminal. It is used primarily to improve connector reliability by retaining the terminal if its lock tangs are not positioned correctly.

If the molded-on Weather-Pack connector is defective, it will require replacement. This means splic-

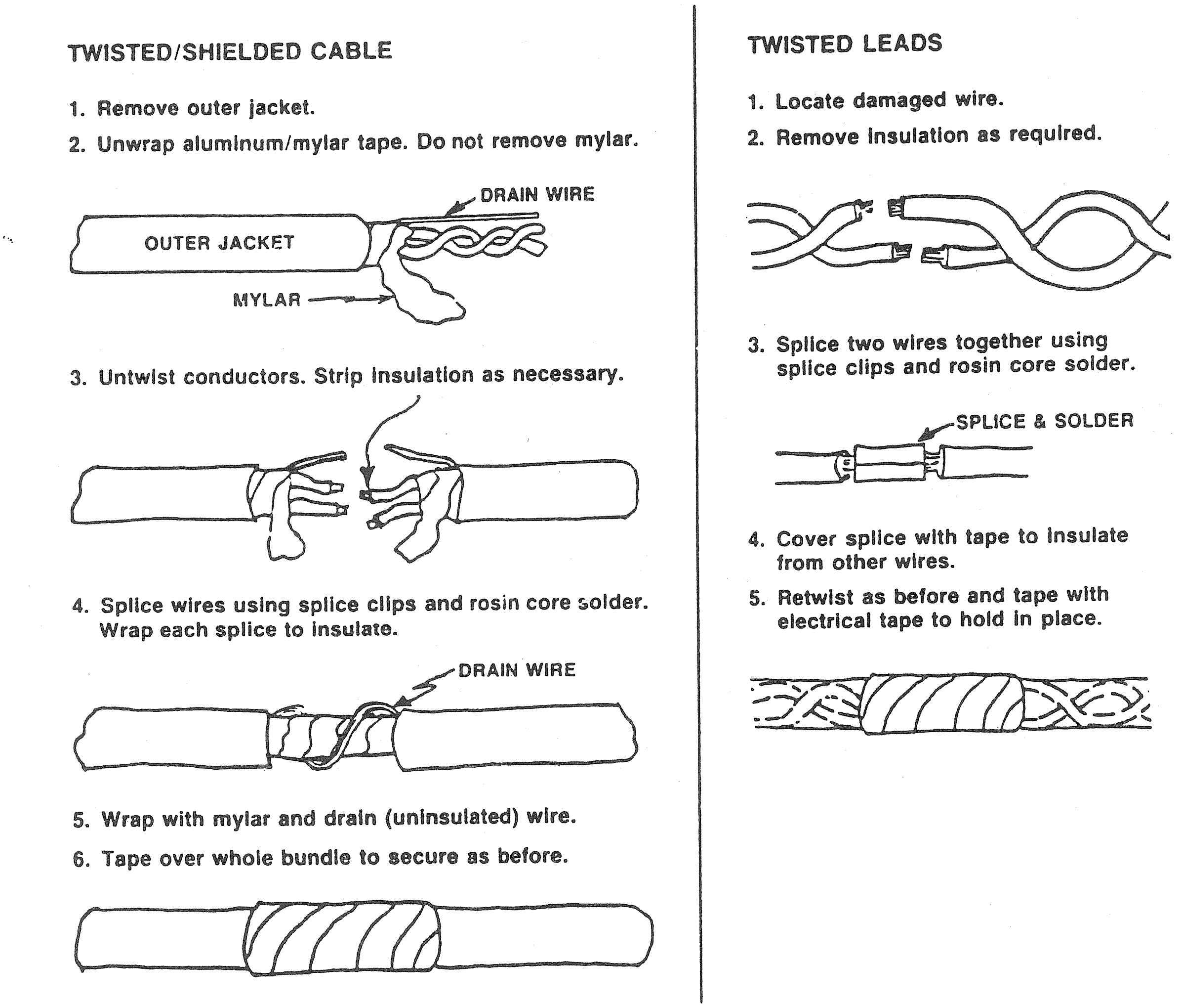


FIGURE 21-23
CCC wiring splice procedures. (Courtesy of General Motors Corp.)

ing a new connector assembly into the harness.

Note: Weather-Pack connectors cannot be replaced with standard assemblies. Also, when single wires are spliced into a harness, use wires with high-temperature insulation only.

With the low voltage and current levels found within the CCC system, it is imperative that the best possible bond at all wire splices be as perfect as possible. Figure 21-23 illustrates the recommended splicing procedure for CCC wiring.

Finally, it is very important that the integrity of Weather-Pack connectors be maintained. Therefore, never break a terminal seal by inserting a probe into the connector. Instead, a voltage reading is obtainable by opening the connector and temporarily installing jumper wires across the circuit(s) to be tested.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete the statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. How do you determine if a replacement ECM is the correct one to use [21-7]?

2. List the items you should check under the hood before performing any diagnostics on the CCC system [21-1].

3. What is the main difference in the procedures for diagnosing carbureted and injected CCC systems [21-6]?

4. What is a determining factor as to what procedure to use when diagnosing a driveability complaint [21-2]?

5. When should you use the diagnostic charts for problems without trouble codes [21-5]?

6. If the ENGINE CHECK light comes on, what is the first step you should perform and why [21-4]?

7. Name the three basic steps in diagnosing a driveability complaint that does not set a trouble code [21-3].

REVIEW

1. A Weather-Pack connector is defective. What needs to be done [21-7]?
   Technician A says a standard connector can be substituted.
   Technician B states a replacement Weather-Pack connector must be spliced into the harness.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b

2. During a diagnostic check, the oxygen sensor is found to be operating too cool. What is wrong [21-1]?
   Technician A says the catalytic converter may be missing.
   Technician B replies the oxygen sensor is defective.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b

3. The PROM burns out immediately after power is connected to the ECM. What is wrong [21-7]?
   a. The PROM was installed backwards in its carrier.
   b. One of its terminals was touched during installation.
   c. both a and b
   d. neither a nor b

4. The CHECK ENGINE light has come on during vehicle operation. What should be done [21-1]?
   Technician A states use a scan tool to check for stored codes.
   Technician B says ground the ALCL test terminal and count the check light flashes to read any stored trouble codes.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b

5. The scan tool shows both integrator and block learn values of 128. The air/fuel mixture is
   a. lean.
   b. 14.7:1.
   c. rich for start-up mode.
   d. rich for acceleration mode.

6. You have just completed some service work on the CCC system [21-2].
   Technician A says to now perform a visual inspection.
   Technician B states to now perform a circuit diagnostic check.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b

7. During the system performance check, the dwellmeter reads 54 degrees [21-6].
   a. This represents a lean ECM command.
   b. This is a normal mixture ECM command.
   c. both a and b
   d. neither a nor b

8. During the circuit diagnostic check, a Code 12 appears [21-2].
   Technician A states this shows there is a hard fault.
   Technician B says this indicates there is an intermittent fault.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b

9. What factor determines which trouble code chart to use [21-4]?
   a. the driveability complaint
   b. whether the problem is a hard fault or an intermittent fault
   c. the trouble code number
   d. both a and b

10. Which of the following trouble codes will appear first [21-1]?
    a. 45
    b. 35
    c. 15
    d. 13

11. The vehicle has an intermittent fault in the CCC system [21-3].
    Technician A says the most likely cause is a defective part.
    Technician B states the most likely cause is a problem within an electrical connection or wiring harness.
    Who is correct?
    a. A only
    b. B only
    c. both a and b
    d. neither a nor b

12. To check EST operation,
    a. ground the ALCL test terminal with the engine running.
    b. ground the ALCL test terminal with the engine shut off.
    c. do both a and b.
    d. do neither a nor b.

13. The CCC system has an intermittent problem. The ENGINE CHECK light will [21-1]
    a. remain off.
    b. stay on.
    c. go off ten seconds after the problem ceases.
    d. flash on and off continuously.

Chapter 22

TYPICAL CHRYSLER EFC AND EFI SYSTEMS

OBJECTIVES

After reading and studying this chapter, you will be able to

- explain the function and describe the design of electronic feedback carburetor (EFC) system input sensors and switches.
- describe the design and function of the EFC system output devices.
- explain the function of the microcomputer used in the EFC system.
- describe the operation of the EFC system.
- explain the function and describe the design of the EFI system input sensors and switches.
- describe the design and function of the EFI system output components.
- explain the functions of the power and logic modules.
- describe the operation of the EFI system.
- explain the design differences between the single-point and multipoint EFI systems.

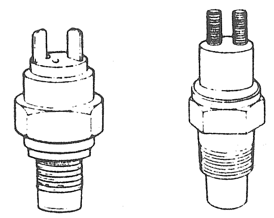


FIGURE 22-1
Typical coolant temperature sensors. (Courtesy of Chrysler Motors Corp.)

Chrysler Motors Corporation introduced its first computerized engine control system in 1979 in California on the 3.7-liter slant 6 engine. This system was known as oxygen feedback or, later, as *electronic feedback carburetor (EFC)* and was little more than the existing but modified spark control computer, an oxygen sensor, and a mixture control solenoid. In 1980, the system was still used on some four-, six-, and eight-cylinder engines.

By 1981, EFC saw service nationwide, and it has continued to be the system utilized on carbureted vehicles. Moreover, since 1981, the microcomputer for the EFC system has had control of a number of emission control functions such as canister purge, EGR, and air switching.

It would be impossible in the space available to cover the many variations of Chrysler computerized systems. For this reason, this chapter provides only an overview of typical EFC, single-point, and multipoint EFI systems.

However, before beginning, there is one important fact to remember. That is, previous chapters have already provided a lot of information about a number of components you are about to study. Therefore, if at any time there is a point you do not understand, use the index or table of contents and go back and restudy the subject material found in earlier chapters of the text.

22-1 EFC SYSTEM INPUT SENSORS AND SWITCHES—TEMPERATURE COMPENSATION

Like the Ford and General Motors microcomputers mentioned in earlier chapters, the Chrysler units are also programmed to respond to changes in coolant or charge temperatures. In other words, the microcomputers' timed output command signals are all compensated for changes in temperature. This compensation is an important consideration during cold engine starts and other low-temperature operating modes, when the microcomputer ignores the oxygen sensor signal and the system operates on preprogrammed data.

There are three basic types of temperature sensors or switches used in Chrysler systems. These include the coolant temperature sensor, coolant temperature switch, and charge temperature sensor.

Coolant Temperature Sensor

A *coolant temperature sensor* is a device that monitors a range of engine operating temperatures (Fig. 22-1). The sensor mounts in the thermostat housing or engine water jacket.

The sensor can have one or two thermistor elements. A thermistor, remember, is a device that changes its internal resistance as temperature goes up or down. Moreover, the sensor resistance is inversely proportional to coolant temperature; that is, when the temperature is high, its resistance is low and vice versa.

The two-terminal, single-element thermistor is used on a number of four-, six-, and eight-cylinder applications. This sensor signal is used by the microcomputer to calculate the correct spark advance and air/fuel mixture and to operate certain emission control devices based on changes in engine temperature.

About 1985, Chrysler introduced a three-terminal, two-element sensor on some transverse engine applications. One element of the sensor provides the signal to the microcomputer that is used to calculate the proper spark advance and air/fuel mixture, and to control the operation of the EGR and canister purge. The second element signal is utilized strictly to control the operation of the radiator fan relay.

Coolant Temperature Switch

Some early four- and eight-cylinder applications use a two-position (open and closed) *coolant temperature switch* in place of a thermistor-type sensor (Fig. 22-2). This device also threads into either the thermostat housing or a water jacket within the intake manifold. In either case, the switch closes at a spe

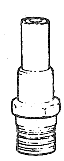


FIGURE 22-2
Typical coolant temperature switch. (Courtesy of Chrysler Motors Corp.)

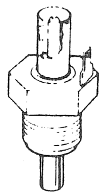


FIGURE 22-3
Charge temperature switch. (Courtesy of Chrysler Motors Corp.)

cific temperature to supply a signal to the microcomputer. The signal is used to prevent the microcomputer from altering the feedback carburetor's programmed air/fuel ratio until the engine reaches a specified temperature. The signal also affects the amount of spark advancement provided by the microcomputer on a cold engine.

Charge Temperature Switch

A number of early six- and eight-cylinder engine applications incorporate a *charge temperature switch* (Fig. 22-3). On the six-cylinder models, the switch threads into the No. 6 intake manifold runner and into the No. 8 runner of the eight-cylinder manifold. In both installations, the switch monitors the temperature of the air/fuel charge.

When the charge temperature reaches a specified amount, the switch closes, and a signal is sent to the microcomputer. Just remember that the charge temperature is raised by a heated air inlet system. This can bring the charge temperature up to its normal operating value before the engine coolant warms up. For conditions such as this, the microcomputer has to know both air/fuel charge and coolant temperature before it can calculate the correct mixture and timing that the engine requires.

Crankshaft Position and Speed Sensors—Pickup Type

On the EFC system, crankshaft position and speed data are provided by either a pickup coil or a Hall-effect switch within the distributor. A single pickup coil provides the signal within a six-cylinder distributor. The eight-cylinder distributor uses two pickup coils for this purpose (Fig. 22-4).

The purpose of the pickup is to generate a voltage signal to the microcomputer. This voltage signal changes each time the distributor shaft reluctor lobe passes the pickup coil pole piece. The metallic lobe causes the induced voltage signal to change from positive to negative or negative to positive (i.e., an AC analog signal).

The signal to the microcomputer has two functions. First, the microcomputer uses the signal to control the operation of the ignition coil primary circuit. Second, the microcomputer uses the signal to determine crankshaft position and speed, or when the engine is in the cranking mode.

Hall-effect Distributor

Chrysler uses a Hall-effect switch in the distributor of all domestic four-cylinder applications in place of a pickup coil. The Hall-effect switch is an electronic device that also puts out a voltage signal providing the microcomputer with crankshaft position and speed data (Fig. 22-5). Additional information on the design and operation of both the Hall-effect and pickup coil distributors can be found in Chapter 8.

Vacuum Transducer

The *vacuum transducer* mounts onto the microcomputer (Fig. 22-6). This unit provides an input signal to the microcomputer that is relative to changes in engine vacuum, which, of course, is an indication of engine load. The microcomputer uses the signal to calculate the correct ignition timing and air/fuel ratio to match engine load conditions.

The vacuum transducer changes mechanical motion into an electrical signal through reactance. *Reactance* is the amount of resistance within an alternating current circuit caused by inductance, and it is measured in ohms. *Inductance* is the induction

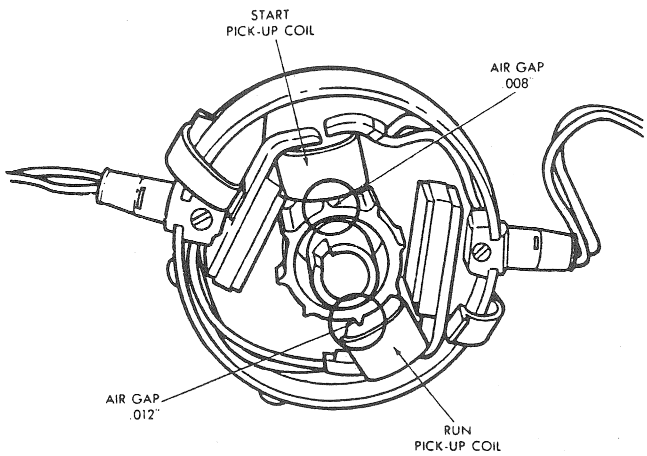


FIGURE 22-4
Distributor with dual pickup coils. (Courtesy of Chrysler Motors Corp.)

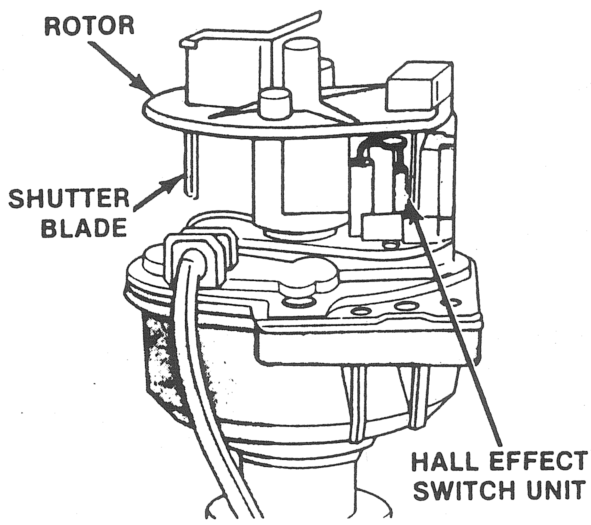


FIGURE 22-5
Hall-effect distributor. (Courtesy of Chrysler Motors Corp.)

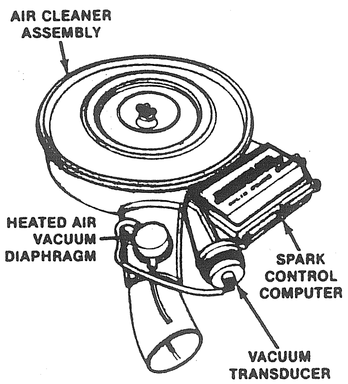


FIGURE 22-6
Vacuum transducer. (Courtesy of Chrysler Motors Corp.)

of a counter voltage in an electric circuit due to variations in current flow through it. The property of inductance creates a voltage drop across the circuit until the voltage source overcomes the effect of the counter voltage and current flow stabilizes. This is the same thing that basically occurs in the primary windings of an ignition coil.

The vacuum transducer consists of a diaphragm that is attached to a moveable metallic core and a coil of wire (Fig. 22-7). The spring side of the diaphragm chamber connects to the intake manifold vacuum on early models and a ported vacuum source on later applications.

With this arrangement, the metal core moves back and forth between the coil windings with changes in engine or ported vacuum. The core, when it is inside the windings, increases the strength of the magnetic field around the coil, since its metal is a far better conductor than air. However, when the core moves away from the center of the coil, the strength of the magnetic field is reduced.

The coil windings surround the core and connect by two terminals to the microcomputer. The microcomputer directs an AC reference voltage through the coil windings to produce an electromagnetic field first in one direction and then in the other around the coil.

The strength of this alternating field will depend on the position of the core as determined by the vacuum diaphragm. For instance, when the vacuum is reduced, the core will be more centered in the coil. This strengthens the magnetic field, which increases its reactance. On the other hand, when the vacuum is high, the core retracts. This weakens the magnetic field and lowers the reactance.

The microcomputer constantly monitors the voltage drop across the coil due to reactance. When there is high vacuum on the diaphragm, the voltage drop is lower and the transducer signal is higher. As vacuum decreases, the voltage drop increases, which effectively decreases the transducer signal. Finally, no matter what the strength of the transducer signal, electronic circuitry converts it into a DC digital signal, which the microcomputer can use in its calculations.

Oxygen Sensor

The *oxygen sensor* for the EFC system threads into the exhaust manifold. The sensor monitors the exhaust gas to provide the microcomputer with an indication of the exhaust gas composition. If the air/fuel mixture is above or below the ideal mixture of 14.7:1, the composition of the exhaust gas is altered, which impairs the efficiency of the three-way catalytic converter.

The oxygen sensor (Fig. 22-8) is supersensitive to the presence of oxygen in the exhaust gas. This is a critical factor. The slightest deviation from the ideal oxygen content in the exhaust gases indicates that the air/fuel mixture is not at 14.7:1.

The oxygen sensor is a voltage-generating device consisting of a cylindrical electrolyte element of zirconium dioxide that is coated inside and out with platinum. The outer platinum electrode is exposed to the hot exhaust gases while the inner one is exposed to the atmosphere.

A porous ceramic (spinel) coating protects the fragile platinum against damage from exhaust gas erosion. In addition, a metal shield, louvered to admit exhaust gases, protects the zirconium dioxide body from breakage during handling and abrasion

by exhaust particulates.

When at operating temperature, the oxygen sensor generates a voltage in relation to the oxygen content within the exhaust (Fig. 22-9). For example, with a high oxygen content (a lean mixture), the sensor generates a low voltage of about 200 millivolts (0.2 volt). On the other hand, a low oxygen content (a rich mixture) causes the sensor to produce a high signal of about 800 millivolts, or 0.8 volt. The sensor voltage with an air/fuel ratio of 14.7:1 is around 450 millivolts (0.45 volt).

The relationship between the available oxygen in the exhaust and sensor output voltage causes it to function as a reliable rich-lean indicator. In other words, the microcomputer uses the sensor signal to calculate and then adjust the air/fuel ratio as necessary to provide the best catalytic converter efficiency while maintaining good driveability.

Throttle Switch

The EFC system does not utilize a throttle position sensor. However, it does have a *throttle switch* located on the end of the idle stop, kicker, or idle control solenoid (Fig. 22-10).

The throttle switch signals the microcomputer when the engine is at closed throttle. As the throttle closes, a lever arm contacts the switch. The lever itself acts as a ground for the signal wire from the microcomputer to the switch.

With this lead grounded, the microcomputer receives a closed throttle signal. This signal is one of the inputs used by the microcomputer to calculate both spark advance and air/fuel mixture.

Detonation Sensor

A piezoelectric *detonation sensor* (Fig. 22-11) is utilized on some four- and eight-cylinder applications. The sensor threads into the intake manifold and generates a low-voltage signal to the microcomputer in response to given knock frequencies.

The microcomputer then retards the timing up to a maximum of 11 degrees. When the detonation condition no longer exists, the microcomputer again advances the timing to the original value before the problem occurred.

Some microcomputers have time-detonation sensor delay circuits. These prevent cold engine noise on the sensor from affecting the ignition timing. However, abnormal engine noises due to worn or damaged parts can input a false signal into the sensor that will retard the timing.

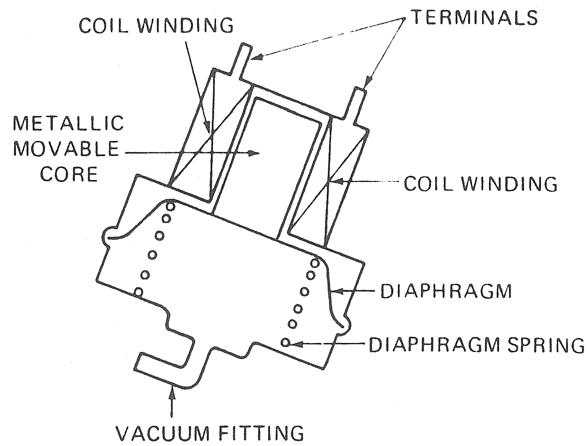


FIGURE 22-7
Vacuum transducer design. (Courtesy of Chrysler Motors Corp.)

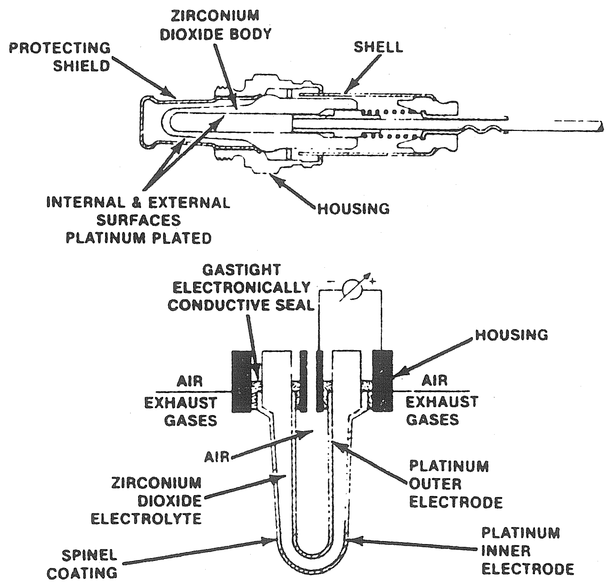


FIGURE 22-8
Oxygen sensor design. (Courtesy of Chrysler Motors Corp.)

22-2 EFC OUTPUT COMMAND SIGNALS

The microcomputer for the EFC system provides a number of output command signals. These signals control ignition timing and the operation of the oxygen feedback, EGR, and air switching solenoids.

Ignition Timing

The ignition timing of the EFC system is controlled by an output driver transistor within the microcomputer. This transistor either opens or closes the cir-

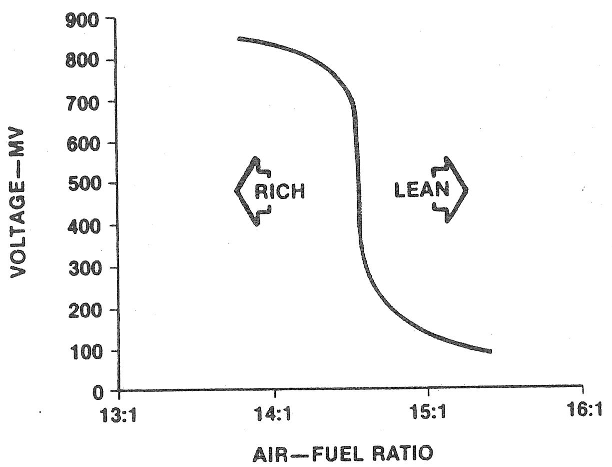


FIGURE 22-9
Oxygen sensor voltage. (Courtesy of Chrysler Motors Corp.)

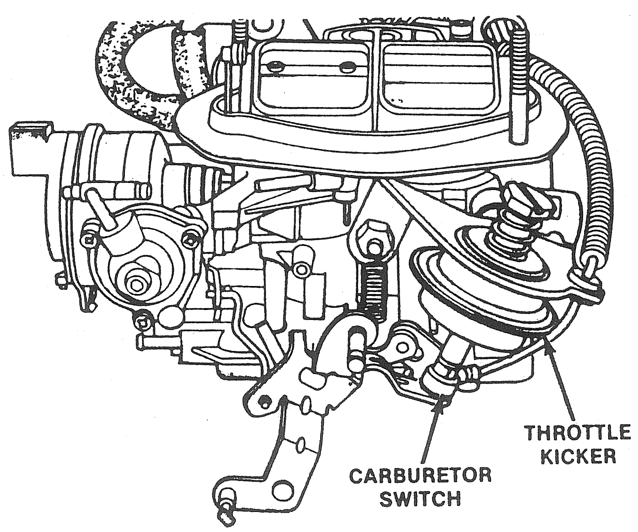


FIGURE 22-10
Throttle switch. (Courtesy of Chrysler Motors Corp.)

cuit from the negative side of the coil to ground, thus breaking or completing its electrical circuit. This action determines when the spark occurs within the cylinders.

The EFC microcomputer provides two other ignition system functions. First, it provides a programmed variable dwell angle that increases timing as vacuum decreases when the engine is cold. This is just opposite to a normal spark retard that other systems provide as the vacuum drops. This particular function helps to improve cold engine driveability. However, when the engine is at normal operating temperature, the cold spark advance feature is cancelled.

In operation, the microcomputer uses the

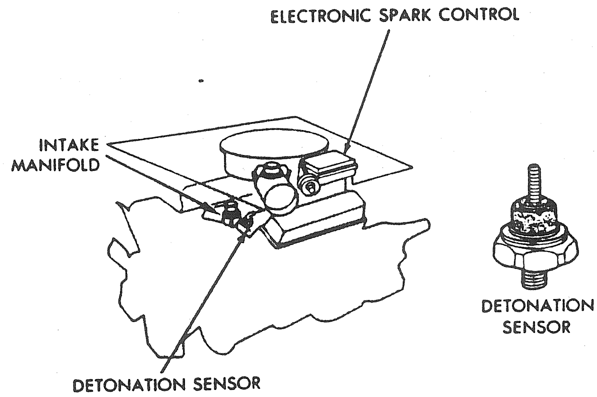


FIGURE 22-11
Detonation sensor. (Courtesy of Chrysler Motors Corp.)

pickup coil signal during cranking to fire all the spark plugs at base timing. Once the engine is running and if cold, the microcomputer adds spark advance based on the coolant temperature, engine speed, and engine vacuum signals.

Once the engine is at normal operating temperature, the microcomputer advances the timing, except at idle, based on engine vacuum and rpm signals. If the engine is at idle with the throttle switch closed, the amount of spark advance based on the vacuum signal is removed.

Oxygen Feedback Solenoids

The EFC system has used three different types of *oxygen feedback solenoids*. These are used to control the air/fuel mixture of the idle and main metering systems on four different types of carburetors. In other words, the solenoid provides regulation of the air/fuel mixture of these feedback carburetor circuits in response to output commands from the microcomputer. The solenoids perform this function by metering air, fuel, or both, and operate in conjunction with conventional fixed air bleeds and fuel metering jets within each carburetor.

Figure 22-12 illustrates a Holley-style solenoid that is used on 6145 and 6520 carburetors. This solenoid consists of a self-contained fuel control valve at the lower end and an air bleed valve on the opposite end. The solenoid has two positions, ON (down) and OFF (up).

The air bleed and fuel control valves operate simultaneously. With the solenoid ON, for instance, the air bleed valve opens, and the fuel control valve closes for leaner operating conditions. Conversely, with the solenoid OFF, the air bleed closes and the fuel valve opens to enrich the mixture.

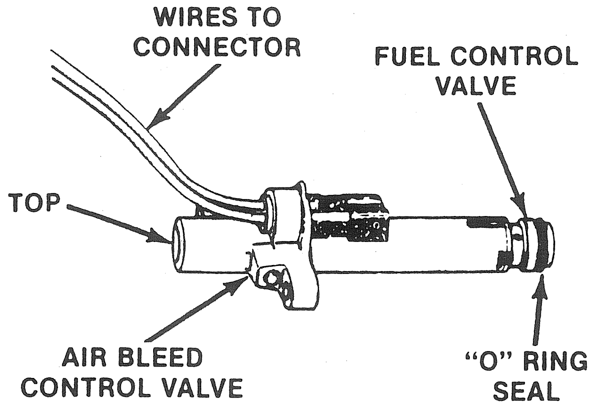


FIGURE 22-12
Holley-style solenoid. (Courtesy of Chrysler Motors Corp.)

Figure 22-13 shows a Carter-style solenoid that is used on BBD and Thermoquad carburetors. This solenoid has a retractable, spring-loaded plunger that opens and closes an air bleed. The solenoid has two positions, ON (open) and OFF (closed). In the ON position, the solenoid plunger retracts and permits the passage of additional air into both the idle and main metering passages for leaner operation. In the OFF position, the plunger is seated and prevents supplemental air from entering these circuits. This results in richer mixtures.

Solenoid Metering Control

Both the idle bleed air and main system fuel flow are regulated between the richest and leanest limits by controlling the percentage of solenoid on-time. Under normal operating conditions, 12 volts is applied to the field windings of the solenoid. The microcomputer actually turns the solenoid on by means of an output transistor that provides a ground circuit for it.

The microcomputer always cycles the solenoid ON and OFF ten times per second (Fig. 22-14). If the microcomputer grounds the solenoid for exactly half the time period of each cycle, it will be turned on for that interval. Therefore, after ten cycles of ON and OFF (one complete second in time), the solenoid will be on 50 percent of the time. The percentage of time in which the solenoid is on is called its *duty cycle*. In this case, it is 50 percent.

If the microcomputer only grounds the solenoid 10 percent of the time, the duty cycle, or solenoid on period is 10 percent (Fig. 22-15). This will result in a very rich mixture. On the other hand, a solenoid that is grounded by the computer 90 percent of the time (a 90-percent duty cycle) provides a

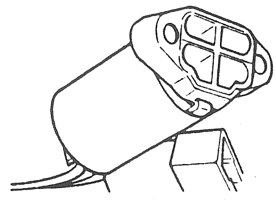


FIGURE 22-13
Carter-style solenoid. (Courtesy of Chrysler Motors Corp).

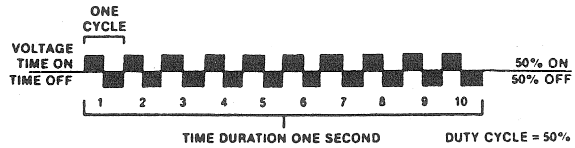


FIGURE 22-14
Ten cycles of solenoid operation. (Courtesy of Chrysler Motors Corp.)

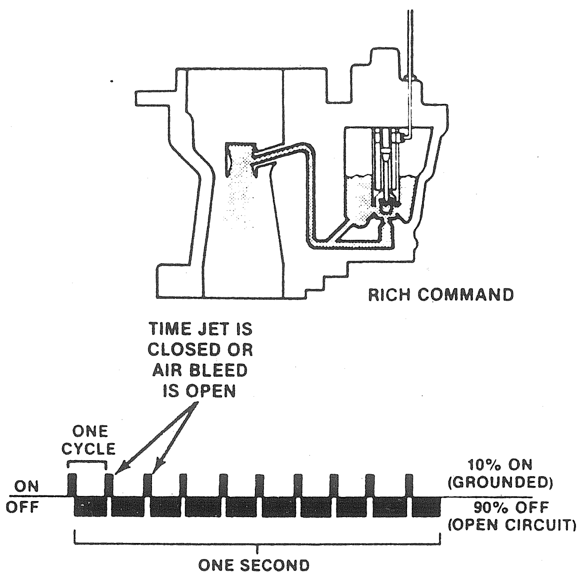


FIGURE 22-15
Ten-percent duty cycle. (Courtesy of Chrysler Motors Corp.)

very lean mixture (Fig. 22-16). It should be obvious that the larger the percentage of time the microcomputer grounds the oxygen feedback solenoid, the leaner the air/fuel mixture will be.

EGR Solenoid

On a number of EFC systems, the control of EGR is not a function of the microcomputer. Fig. 22-17 illustrates a typical noncomputerized system in which the vacuum signal that activates the EGR valve is regulated by a delay timer, delay solenoid,

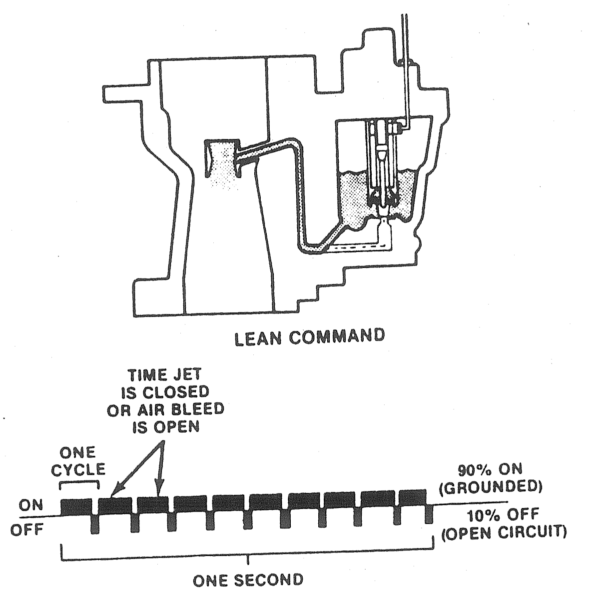


FIGURE 22-16
Ninety percent duty cycle. (Courtesy of Chrysler Motors Corp.)

and a coolant-controled engine vacuum switch. This particular system is covered in Chapter 14.

In a microcomputerized system, the timer, delay solenoid, and vacuum switch are not needed. Their functions are taken over by the microcomputer and a single *EGR solenoid*. This solenoid (Fig. 22-18) is one of an identical pair, one used to control the EGR vacuum signal and the other to control the signal to the air switching valve.

Both units are normally closed, solenoid-operated vacuum valves. In operation they not only turn off or on the vacuum signal to the appropriate device, but also vent a given circuit when de-energized by the computer.

Notice in Fig. 22-18 that the solenoids require

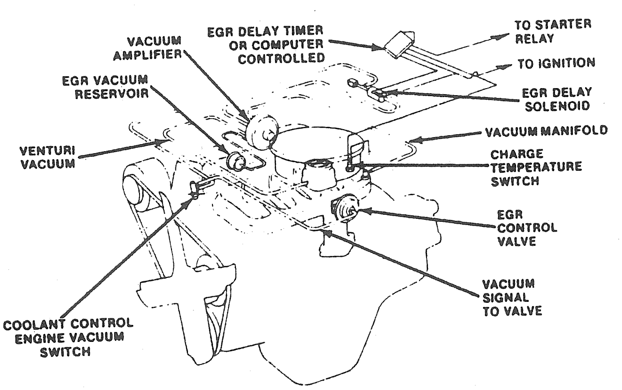


FIGURE 22-17
Typical noncomputerized EGR system. (Courtesy of Chrysler Motors Corp.)

two wires each. This indicates that the system supplies power to the solenoids at all times when the ignition switch is on. To complete the circuit to one or both of the solenoids, the microcomputer just provides a ground circuit through an output driver transistor.

Whenever the microcomputer determines that EGR is needed, the output driver transistor completes an internal ground for Pin 11 (Fig. 22-19). With Pin 11 grounded, the electrical circuit through the EGR solenoid is complete, and it energizes.

This action opens the solenoid vacuum valve. As a result, the vacuum signal can act on the EGR diaphragm, and exhaust gas recirculation begins. The actual amount of EGR flow is determined by the strength of the vacuum signal and the solenoid's duty cycle programmed into the microcomputer.

Air Injection Solenoid

As in the case of the EGR system, not all EFC systems provide microcomputer control of air injection switching. In a system where this is not a function of the microcomputer, a coolant-controlled vacuum

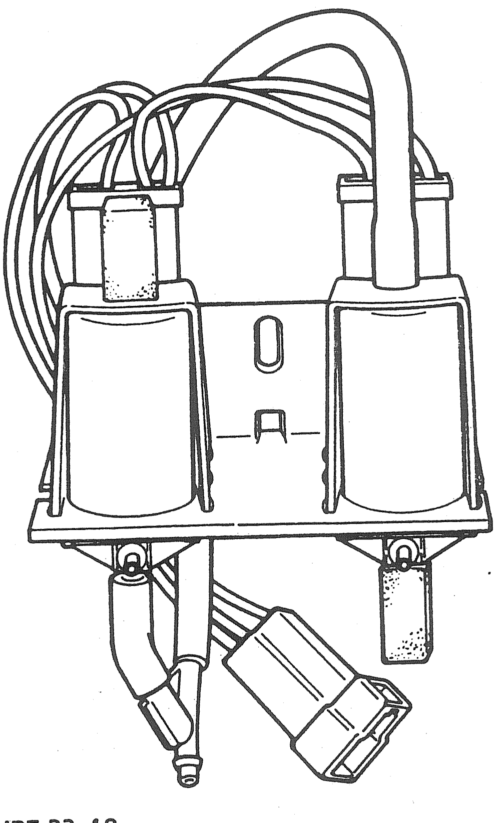


FIGURE 22-18
EGR and air switching solenoids. (Courtesy of Chrysler Motors Corp.)

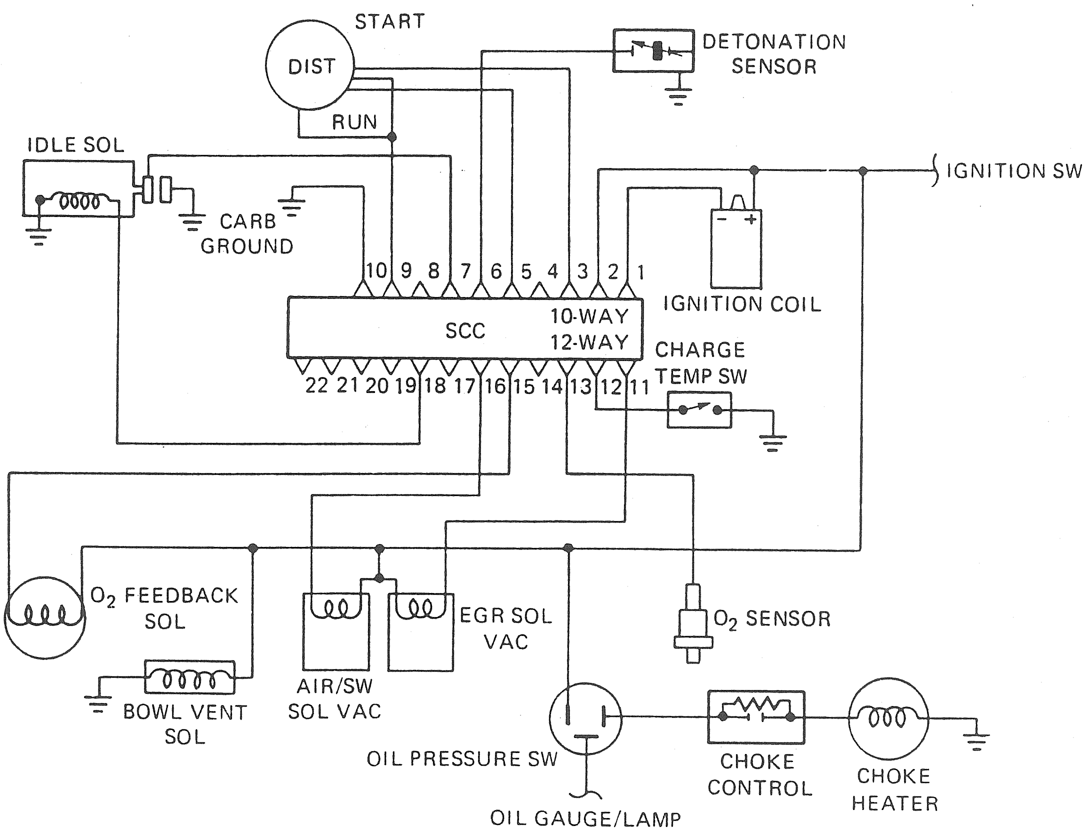


FIGURE 22-19
Partial schematic of a typical EFE system.

valve regulates the vacuum signal to the switching valve (Fig. 22-20).

If air switching is a function of the microcomputer, a solenoid controls the vacuum signal to the air switching valve (see Fig. 22-18). This solenoid also receives 12 volts to one of its terminals when the ignition switch is turned on. The other terminal connects to Pin 16 of the microcomputer connector. To energize the solenoid, the microcomputer provides a ground for Pin 16 through an output driver transistor (see Fig. 22-19).

During cold engine operation and for a short period after each engine start-up, the microcomputer grounds the solenoid and it energizes. As a result, the switching valve receives a vacuum signal and opens. Pump air is now directed by the switching valve to the upstream location.

When the engine is at normal operating temperature and the EFC system is in closed loop, the microcomputer de-energizes the solenoid. This cuts off the vacuum signal to the air switching valve, and it closes the upstream port and opens the downstream passage. Consequently, air is directed to the downstream location.

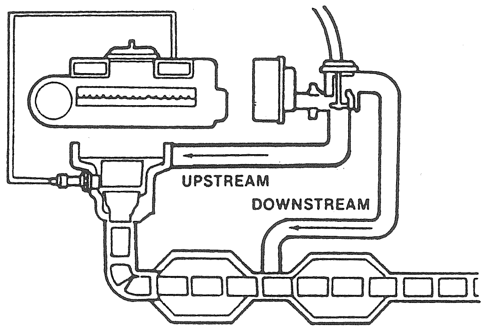


FIGURE 22-20
Air switching control valve and system. (Courtesy of Chrysler Motors Corp.)

System Diagnostics

Before 1985, the EFC system did not have built-in system diagnostics as an output function of the microcomputer. From 1985 on, the EFC microcomputer is programmed with self-diagnostic capabilities. The microcomputer can monitor certain engine systems and components. If a problem is detected

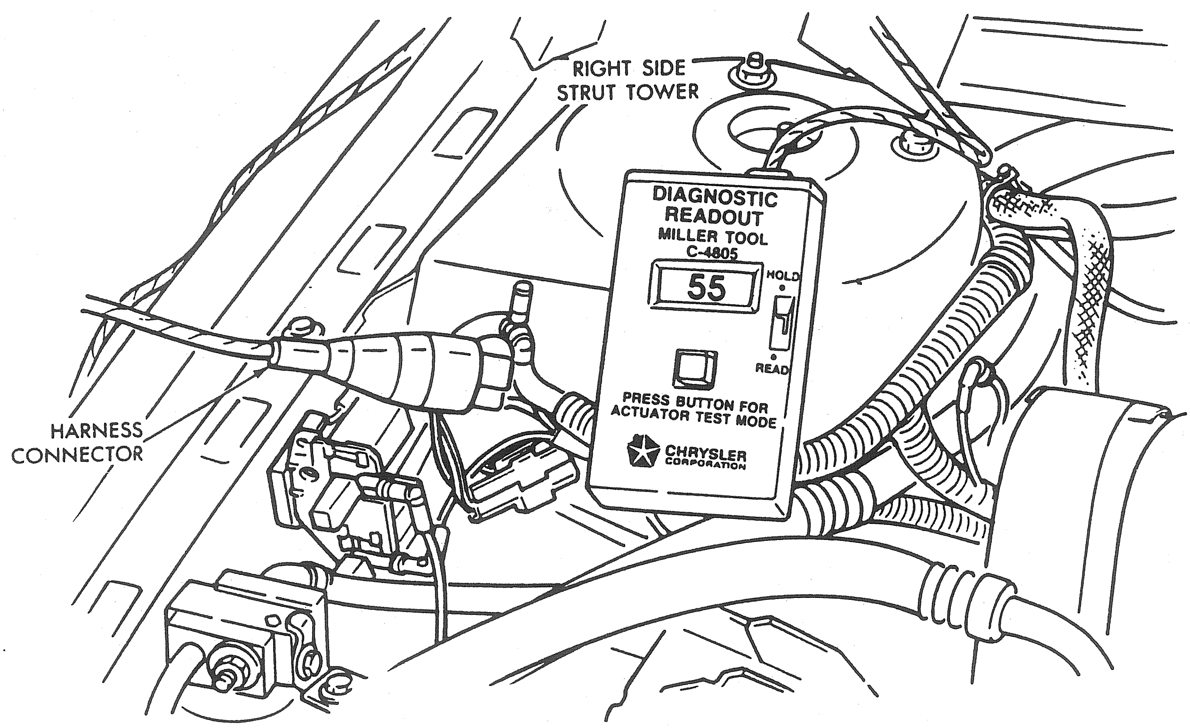


FIGURE 22-21
Diagnostic readout box. *(Courtesy of Chrysler Motors Corp.)*

in any monitored system or part, a fault code is stored in memory as an aid to diagnosis. However, if a detected problem is repaired or fails to repeat itself within 20 to 40 ignition switch on/off cycles, the microcomputer cancels the code.

A diagnostic readout box (Fig. 22-21) that plugs into a diagnostic connector under the hood is used to recall the stored codes. The readout box can also be used to check four different system modes, as explained in the next chapter.

22-3 EFC MICROCOMPUTER AND SYSTEM OPERATION

The microcomputer for the EFC system is called the *spark control computer (SCC)* or the *combustion control computer (CCC)*. On the earlier applications, the computer was located on the air cleaner (see Fig. 22-6). On later models, it can be located in other areas of the engine compartment.

SCC or CCC Design

Like the microcomputers discussed in earlier chapters, the SCC or CCC consists of a number of components that make up its hardware and software sections (Fig. 22-22). The computer receives input signals through its hardware section known as the *central processing unit (CPU)* or *microprocessor*. Moreover, from it come the output command signals to the various control devices. In other words, the CPU or microprocessor is where the calculation and logic decisions are made after information is drawn from memory.

Computer software is made up of programs or sets of instructions stored in memory that are accessed by the microprocessor. The hardware processes the software. Also, changes can be made to the software to alter the computer's operation without having to modify the hardware. As a result, different vehicles can use basically the same hardware package but have different software tailored to a particular engine, transmission, or vehicle weight configuration. The software that stored this type of information in memory is called the *Programmable Read Only Memory (PROM)*.

The computer also has two other types of memory. The *Read Only Memory (ROM)* is permanently stored data. The information in this memory is unchangeable and enables the computer to immediately begin its operation when turned on. Lastly, ROM memory is not lost when battery voltage is disconnected from the computer.

Random Access Memory (RAM) is a type of

memory that can be added to as well as read from. RAM stores data on sensor input, system performance, calculations, and diagnostic codes. If battery power is lost to the computer, RAM memory is erased.

Once power is connected to the computer, the ROM will get the system started, and the RAM database will again begin building up over a short period of time. However, it is not unusual for system performance to be off slightly until portions of RAM have had sufficient time to establish a database.

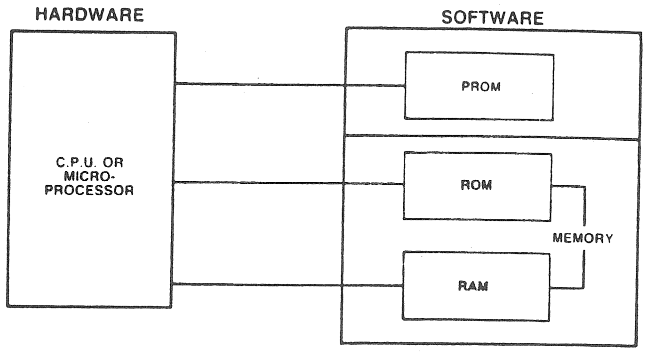


FIGURE 22-22
Components of the SCC or CCC. (Courtesy of Chrysler Motors Corp.)

System Operation—Open Loop

To achieve the best overall driveability at varying engine temperatures and operating conditions, the EFC system has two modes of operation, open and closed loop.

The EFC system operates in *open loop* under the following conditions: cold engine, hot engine restart, low manifold vacuum, high manifold vacuum, and idle (only on some engines).

During cold engine operating conditions, the computer is programmed to provide predetermined, oxygen-feedback, solenoid duty cycles. This allows the carburetor to produce fixed air/fuel mixtures programmed for good driveability.

The EFC computer determination of cold engine open loop is based on

- Coolant temperature. The coolant temperature sensor signals are used by the computer to measure how much the engine has warmed up. Below a specified temperature, open loop is mandated. Between predetermined temperatures, the control of open loop is by cold restart time and, in some cases, the signal from the charge temperature sensor.

- A cold restart timer. The timer is needed to delay closed loop operation until the oxygen sensor has warmed up sufficiently to produce a reliable voltage and be clear of starting deposits. As opposed to just using the coolant sensor signals alone, the addition of the timer provides more predictable control due to the warm-up variations within the cooling and exhaust systems.

- A charge temperature sensor signal, in addition to the cold restart time, on six- and eight-cylinder EFC systems. This prevents early closed loop operation when an engine is hot, but the outside air temperature is cold. When the engine is warming up under these conditions, a cold intake charge can keep the exhaust temperatures low enough to prevent the oxygen sensor from reaching its normal operating temperature. It is therefore important to keep the system in open loop under these conditions.

When a hot engine is restarted, a short period of time is necessary to wait until the oxygen sensor has warmed up and is clear of starting deposits. To accomplish this, the EFC system has a hot restart delay that prevents closed loop operation any time the engine is started with coolant and charge temperatures above a specified amount. While in open loop under these conditions, the computer provides a hot duty cycle to the oxygen feedback solenoid.

When a cold engine is accelerated to a point in which its vacuum drops below a specified amount, the computer provides a rich duty cycle to the oxygen feedback solenoid. This prevents acceleration stumble or engine stalling. Moreover, some engine calibrations may call for the computer to revert to this operating mode, even if in closed loop, if the vacuum drops low enough.

The EFC computer on some four-cylinder engines is programmed to prevent closed loop operation at idle. This guarantees a richer than normal air/fuel mixture for better idle quality.

During an extremely high manifold vacuum condition during deceleration, the computer is programmed to switch to open loop. The computer than provides a fixed lean oxygen solenoid duty cycle to reduce HC and CO emission levels and save fuel. The system returns to closed loop when the vacuum returns to normal; that is, if the coolant and oxygen sensors are both at normal operating temperature.

Below a given temperature, during open loop, the computer de-energizes the EGR solenoid to prevent exhaust gas recirculation. It provides the correct amount of spark timing plus energizes the switching solenoid so that pump air passes to the upstream location.

Closed Loop

During open loop, the SCC or CCC monitors the input signals, as shown in Fig. 22-23. The computer will switch the system into closed loop when the coolant temperature has reached a specified value, the charge temperature on certain engines has reached a predetermined value, the oxygen sensor is warmed up and supplying a reliable signal, a specified amount of time has passed since the engine has started, and a four-cylinder engine is running above idle.

During closed loop, the computer varies the oxygen feedback solenoid duty cycle according to inputs from the vacuum transducer that monitors engine load, the pickup coil that indicates engine rpm, and the oxygen sensor that monitors the amount of oxygen remaining in the exhaust gases.

Also during closed loop, the computer directs output commands to provide the correct spark timing, energize the EGR solenoid to provide exhaust gas recirculation, and de-energize the switching solenoid so that pump air passes to the downstream location at the catalytic converter.

22-4 SINGLE-POINT EFI SYSTEM INPUTS

Chrysler introduced the single-point EFI system in 1984, and it is still in current use. This arrangement is a computer-controlled throttle body, single-point pulsating fuel injection system that provides a precise air/fuel ratio for all driving conditions. Moreover, the computer for this system regulates ignition timing, air/fuel ratio, idle speed, and emission control devices.

Various sensors provide the inputs necessary for the computer to perform the above mentioned functions (Fig. 22-24). These include the manifold absolute pressure (MAP) sensor, throttle position (TP) sensor, coolant temperature (CT) sensor, oxygen feedback sensor, Hall-effect distributor, and vehicle speed (VS) sensor.

In addition to these sensors, various switches also provide the computer with other important data. These switches include the park/neutral safety, heated backlite, air conditioning, and air conditioning clutch.

MAP Sensor

The *manifold absolute pressure (MAP) sensor* (Fig. 22-25) develops a signal to the microcomputer relative to manifold vacuum, and thus engine load conditions. This signal, as well as those from other sensors, is used to determine the correct air/fuel ratio. As intake manifold pressure increases (vacuum decreases), for example, additional fuel is necessary. In this case, the MAP signal to the microcomputer causes it to increase injector pulse width. Conversely, as manifold pressure decreases (vacuum increases), the computer shortens the pulse width as a result of the MAP signal.

The MAP signal and other inputs also deter-

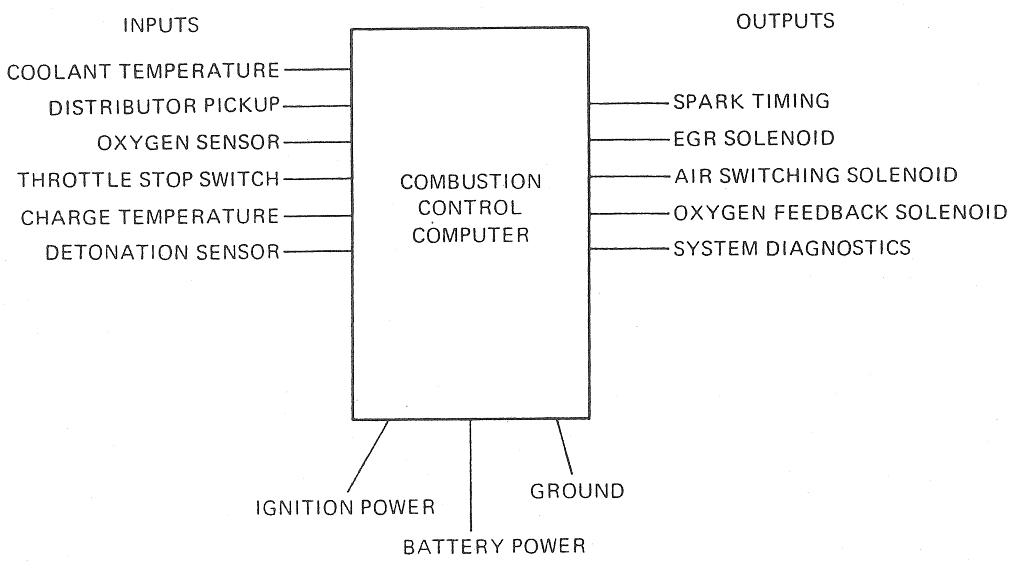


FIGURE 22-23
EFI inputs and outputs during closed loop operation.

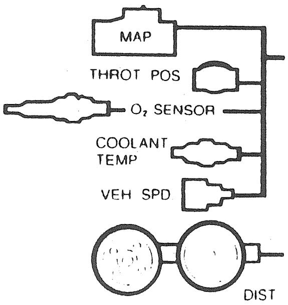


FIGURE 22-24
EFI sensor inputs. (Courtesy of Chrysler Motors Corp.)

mine the correct amount of spark advance. For instance, the microcomputer uses the MAP signal and that from the CT sensor to determine the spark advancement based on engine load and temperature. The spark advancement has to be varied for different load conditions and for cold and warm engines, as well as temperatures in between.

The MAP sensor itself is a piezoresistive device similar in design and operation to the General Motors device. This sensor is located inside the vehicle, mounted above the logic module. The MAP senses barometric pressure as the key is turned on and uses it as a reference point to determine the intake manifold absolute pressure. The MAP also has a port that connects the sensor via a hose to a vacuum fitting on the throttle body, located below the throttle blade.

The logic module supplies a reference voltage of five volts to the MAP sensor. With changes in engine vacuum, the MAP signal increases or decreases proportionally. For example, the approximate sensor voltage at zero vacuum (atmospheric pressure) is 4.9 volts. At maximum vacuum, the output voltage may drop to as low as 0.3 volt.

Throttle Position Sensor

The *throttle position (TP) sensor* attaches to the end of the throttle shaft on the side of the throttle body (Fig. 22-26). The TP sensor signal is utilized along with other sensor input by the computer to adjust the air/fuel ratio during acceleration, deceleration, wide-open throttle, and idle.

The TP sensor is a rotary-type potentiomenter that receives a five-volt reference voltage from the logic module. Since the TP sensor is a potentiometer, it delivers a signal that is proportional to the throttle blade opening. The range of the signal is from over 0.16 volt at closed throttle to less than 4.7 volts at wide-open throttle.

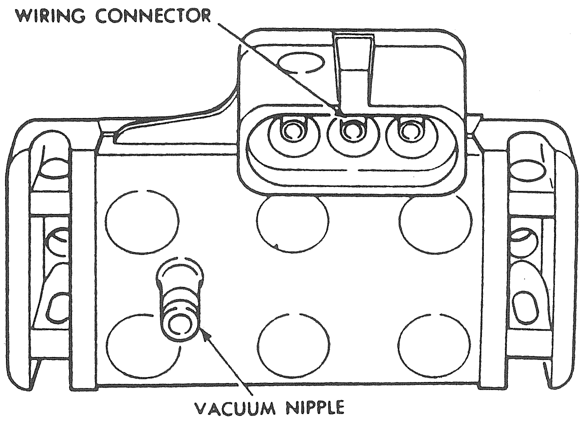


FIGURE 22-25
MAP sensor. (Courtesy of Chrysler Motors Corp.)

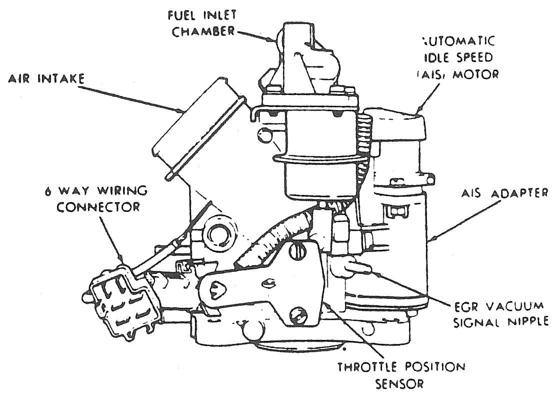


FIGURE 22-26
TP sensor. (Courtesy of Chrysler Motors Corp.)

Coolant Temperature Sensor

The *coolant temperature (CT) sensor* is located in the thermostat housing (Fig. 22-27). The CT sensor is a single-element thermistor that has a resistance value of 11,000 ohms at $-4°F$ ($-20°C$) to 800 ohms at 195°F (90.5°C). The latter value is considered to be the normal operating temperature of the engine.

The microcomputer directs a reference voltage of five volts to the sensor. It then measures the amount of voltage drop across its varying resistance as engine temperature changes. The amount of voltage drop constitutes the CT sensor signal.

The CT sensor is just one of the inputs to the microcomputer that results in changing idle speed, air/fuel ratio, and spark timing for all engine operating conditions. When a vehicle is cold, the idle speed is increased, the air/fuel ratio is enriched, and spark advance curves are altered to improve cold engine operation. Moreover, since the engine temperature

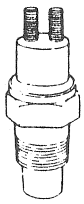


FIGURE 22-27
CT sensor. (Courtesy of Chrysler Motors Corp.)

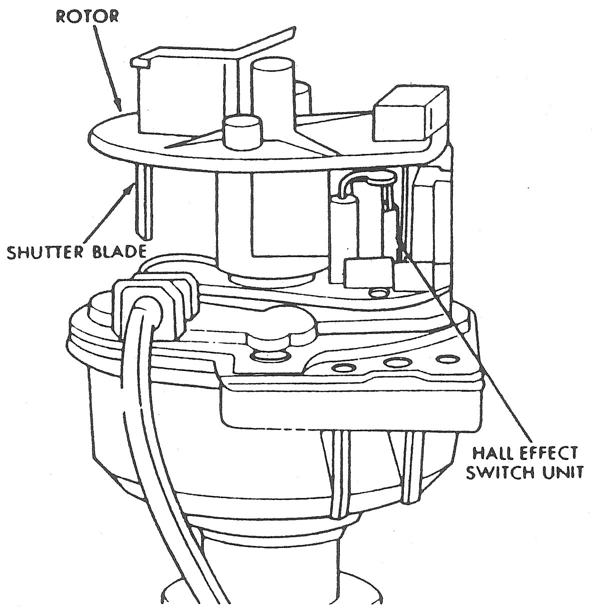


FIGURE 22-28
Hall-effect distributor. (Courtesy of Chrysler Motors Corp.)

is constantly changing during the warm-up period, these factors are regularly updated and changed.

When the engine reaches normal operating temperature, as signaled by the CTS, the microcomputer maintains a programmed idle speed to prevent engine stalling. In addition, the air/fuel ratio is maintained at 14.7:1, and spark advance curves are established to improve fuel economy, lower emissions, and promote driveability.

Oxygen Feedback Sensor

The oxygen feedback sensor in the EFI system has the same basic design and function as the one used for EFC. However, some applications use a three-wire sensor for incorporating an internal heating element.

There is also an operating change relative to the sensor signal during closed loop. That is, the microcomputer can override its signal during rapid acceleration, indicated by drastic changes in MAP or

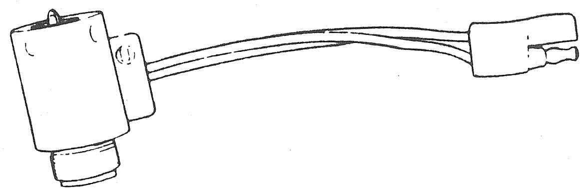


FIGURE 22-29
Vehicle speed sensor. (Courtesy of Chrysler Motors Corp.)

TP sensor signals, to provide additional fuel enrichment.

Hall-effect Distributor

A *Hall-effect distributor* supplies the EFI microcomputer (the logic module) and the power module with engine rpm and crankshaft position input signals (Fig. 22-28). The Hall-effect switch receives an input voltage of eight-volts from the power module, which it converts to a pulsing digital signal as the distributor shaft rotates.

The logic module uses these signals for two purposes. First, the signal supplies engine speed data to determine spark advance. Second, it is utilized to determine piston position so that fuel injection will occur at the proper time.

The distributor signal that is sent to the power module causes it to ground the automatic shutdown relay. The relay, in turn, closes voltage circuits to the fuel pump, logic module, ignition coil (+) terminal, and injector and ignition coil drive circuits of the power module. If the relay does not receive the distributor signal or it is not correct, it will not energize.

Vehicle Speed Sensor

The *vehicle speed (VS) sensor* is located in the connection between the speedometer cable and transmission, and it is used by the logic module to monitor vehicle motion (Fig. 22-29). The sensor receives a five-volt signal through a resistor from the logic module. Since the VS sensor is a simple on/off micro switch, it changes the steady logic module five-volt input into eight pulse signals per speedometer cable revolution.

The logic module uses the VS and TP sensor signals to differentiate between a closed throttle deceleration and a normal idle with the vehicle stationary. Under deceleration, the logic module can then control the automatic idle speed motor to maintain a given airflow to reduce HC and CO emissions. Dur-

ing stationary operation, the logic module controls the airflow to maintain a desired engine speed.

EFI Switch Inputs

The logic module also receives input signals from a number of switches (Fig. 22-30). The signals from these switches are used by the module to adjust engine idle speed via the automatic idle speed (AIS) motor. However, the logic module does use some of the signals to provide additional control of spark timing and injector pulse width.

The *park/neutral safety switch* is found on vehicles with automatic transmissions. This switch signals the computer if the transmission is in park, neutral, or a driving gear. The module uses the signal to provide different idle speeds for these selector lever positions and to prevent normal timing curve advancement unless the transmission is in a driving gear.

If the vehicle has an *electric backlite (heated rear window)* and its switch is turned on, a signal is sent to the logic module. The module, in turn, energizes the AIS motor to increase engine speed at idle. This action compensates for the additional load placed on the engine by the alternator.

The *brake switch* directs a signal to the logic module any time the brakes are applied. The module uses this as an idle signal in the event it does not receive a closed throttle signal from the TP sensor. An idle signal is necessary in order for the module to provide the correct pulse width for idle operation.

The *air conditioning switch* sends a signal to the logic module whenever it is turned on. The logic module then energizes the AIS motor to increase idle speed to compensate for compressor load on the engine idle.

The *air conditioning clutch switch* signals the logic module whenever the compressor cycles on and off. The module will then energize the AIS motor to provide a one-time increase in idle speed to compensate for compressor load.

22-5 SINGLE-POINT EFI SYSTEM OUTPUT DEVICES

The logic module for the single-point system provides output commands to a number of units (Fig. 22-31). These include the fan relay, EGR and purge solenoids, A/C cutout relay, AIS motor, diagnostic output, fuel pump, injector, and spark timing.

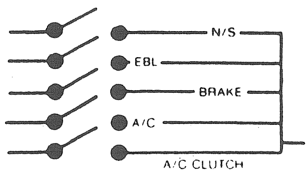


FIGURE 22-30
EFI switch inputs. (Courtesy of Chrysler Motors Corp.)

Fan Relay

The *fan relay*, when energized by the logic module, provides power to the cooling fan. The logic module energizes the relay when coolant temperature reaches a specified value by providing a ground for its switching coil. With the coil grounded, current flows through it, resulting in a magnetic field that pulls the relay contacts closed. The closed contacts complete the power circuit to the fan.

EGR Solenoid

The *EGR solenoid* operates a valve that controls the ported vacuum signal to the EGR valve. The solenoid valve is normally open. However, when grounded by the logic module, the solenoid energizes and not only blocks the signal to the EGR valve but bleeds off any vacuum trapped in the circuit. The solenoid is energized when coolant temperatures are below 70°F (21°C), when engine speeds are below about 1,200 rpm, at wide-open throttle, and for a period of time after engine start-up.

Canister Purge Solenoid

The *canister purge solenoid* has the same design and operates in the same way as the EGR unit. However, the purge solenoid controls the vacuum in a line from the throttle body to the carbon canister purge valve. When the solenoid is de-energized, vacuum is applied to the valve and canister purging occurs.

But when the logic module grounds the solenoid, the vacuum is blocked to the purge valve. This will occur whenever the coolant temperature is below 180°F (82°C).

A/C Cutout Relay

The *A/C cutout relay* is located in the engine compartment on the left shock tower. This normally open relay is in the air conditioning compressor clutch ground circuit. The open relay prevents the

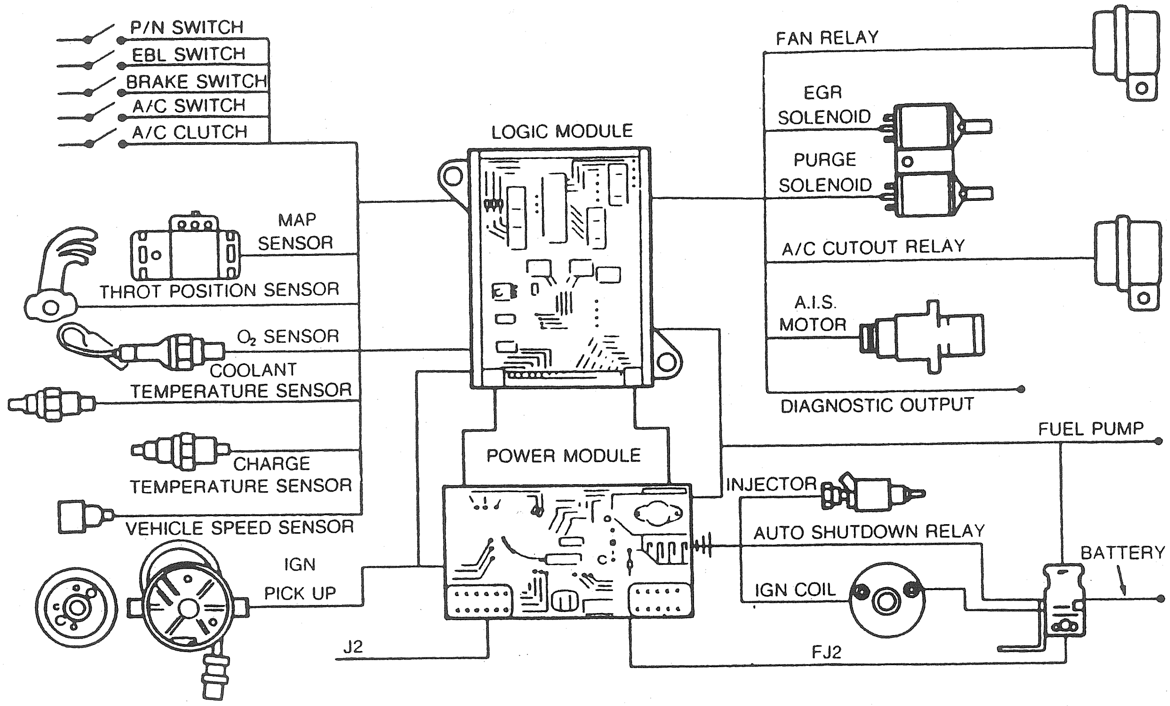


FIGURE 22-31
EFI system outputs. (Courtesy of Chrysler Motors Corp.)

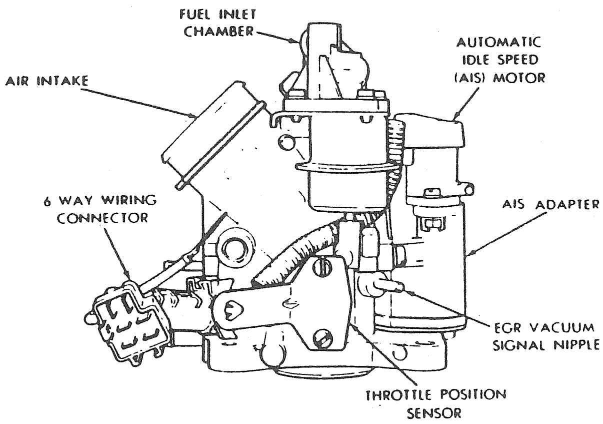


FIGURE 22-32
AIS motor location. (Courtesy of Chrysler Motors Corp.)

clutch from energizing, even with the A/C switch on, when the engine is operating at wide-open throttle, when the engine speed is below 500 rpm, and when the engine is cranked.

The relay itself is energized through a ground provided by an output driver transistor within the logic module. The logic module will ground the cutout relay switching coil and therefore complete the clutch ground circuit whenever the engine is running, except for those conditions listed above. However, the compressor clutch will still not operate unless the A/C switch is turned on.

Automatic Idle Speed Motor

The *automatic idle speed (AIS) motor* mounts onto the throttle body assembly (Fig. 22-32). The motor controls idle speed at closed throttle positions to prevent stalling. On deceleration, the motor also increases idle speed to reduce stalling and lower HC and CO emissions.

The basic (no-load) idle results from a minimum airflow through the throttle body. The reversible AIS motor can then adjust the air portion of the air/fuel mixture through an air bypass on the back of the throttle body. This is accomplished by moving a valve to control the airflow through a channel in the throttle body that bypasses the throttle blade. With the valve in its most closed position, enough air passes through the throttle body to support a no-load minimum idle speed. The AIS motor opens the valve to increase idle speed as needed to compensate for engine load or ambient conditions.

The AIS motor operates by means of an output signal from the logic module. This signal provides a ground for one of the two coils within the motor. In this way, the module adjusts engine rpm for the best idle under all conditions using input signals from the throttle position sensor, speed sensor, coolant temperature sensor, electrical backlite switch, air conditioning switch, air conditioning clutch switch, park/neutral safety switch, and brake switch.

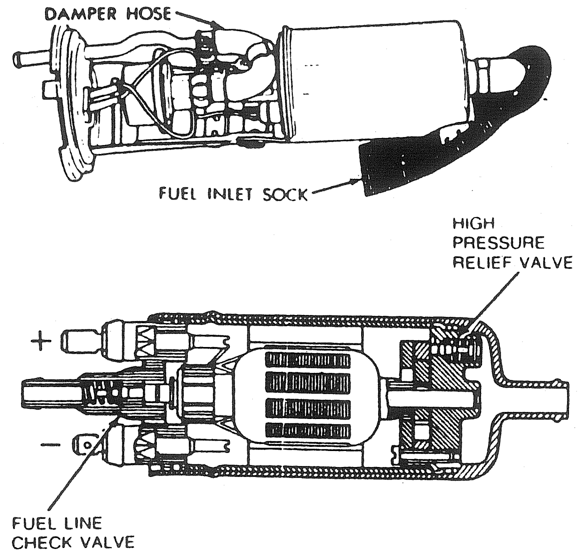


FIGURE 22-33
Fuel pump. (Courtesy of Chrysler Motors Corp.)

Diagnostic Output

The EFI system also has an on-board diagnostics system. The logic module monitors critical input and output circuits of the system to make sure they are operating satisfactorily. Some of these are checked continuously while others are checked under certain conditions.

If the diagnostic system senses that one of the critical circuits is malfunctioning during a predetermined amount of monitoring period, it will consider this to be a real problem and set a fault code in memory. As a diagnostic output, the logic module then illuminates the *power loss lamp* on the dash.

The lamp also comes on each time the ignition key is turned on and stays on for a few seconds as a bulb test. It can also be used to display some trouble codes. However, it does not have the capability of diagnosis, which is provided by the readout box that plugs into the underhood diagnostic output connector.

Fuel Pump

The *fuel pump* is the positive displacement type (Fig. 22-33). The pump is the roller vane design, powered by a permanent magnet electric motor. The pump and its motor are fitted into a common housing within the fuel tank and are thus continuously surrounded by fuel.

Electric current to operate the fuel pump is supplied through the automatic shutdown relay, which is controlled by the power module. When the contacts of this relay close, battery voltage is supplied to the pump. The ground circuit for the pump is through the vehicle chassis.

Fuel Injector

The *fuel injector* is a pintle valve located in the throttle body that is controlled by an electric solenoid (Fig. 22-34). The fuel injector receives battery voltage from the power module. However, the logic module determines how long and when the injector operates by providing it with a drive (ground) circuit also through the power module.

The logic module electronically pulses the injector once for each piston intake stroke. The logic module also changes the pulse width to meet all operating conditions. *Pulse width* is the length of time in milliseconds that the injector is open (energized) and emitting fuel to the bore of the throttle body.

When the injector is grounded by the power module, current flows through its solenoid coil. Its magnetic field then causes the armature and pintle to move a short distance against spring tension. Fuel passes, under pump pressure, through the injector to the outlet orifice and pintle at the base of the injector. The pintle design causes a fine spray to be developed in the shape of a hollow cone. This fuel spray mixes with the air as it flows through the throttle body.

The amount of fuel delivered must ensure that driveability, performance, fuel economy, and emission requirements are satisfied as much as possible. However, depending on the operating mode, one of these considerations normally takes precedence over the others. For example, in the case of a warmed up engine operating at a relatively steady road-load condition, the emissions consideration takes precedence. In other words, to provide the best control of emissions by the catalytic converter, the injector must provide an air/fuel ratio of 14.7:1.

Since a logic module output command controls pulse width, it is necessary to establish relationships

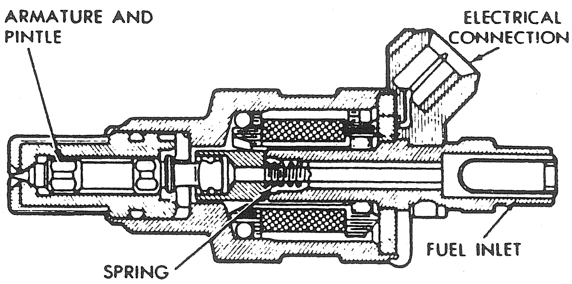


FIGURE 22-34
Fuel injector. (Courtesy of Chrysler Motors Corp.)

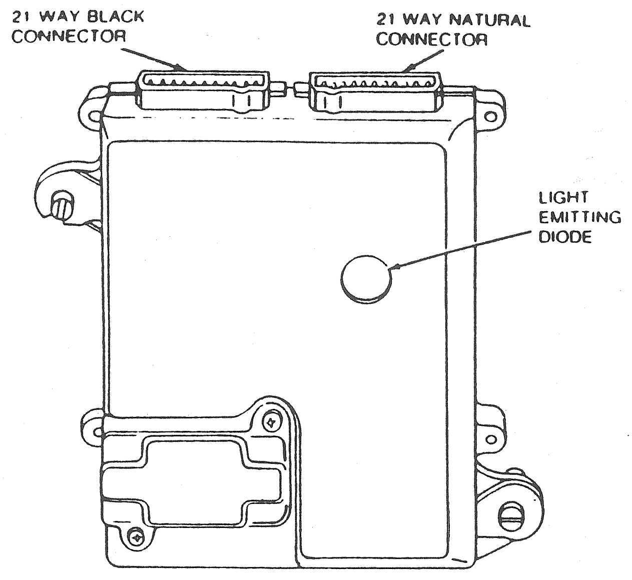


FIGURE 22-35
Logic module. (Courtesy of Chrysler Motors Corp.)

between some measured input signals and injector on-time in order to provide the correct mixture. To do this, the logic module uses a *speed density approach* in which engine rpm and MAP signals are its primary inputs for this function.

In practice, extensive engine testing establishes the direct relationship between these inputs and pulse width. The results of these tests are converted into data programmed into memory cells. The logic module then uses the data from these cells to calculate the correct pulse width based on MAP and rpm signals.

Ignition Timing

The logic module controls the amount of ignition timing (the advancement curve) through all engine operating phases. It does so by regulating the operation of the ignition coil's ground driver circuit within the power module. In other words, the logic module determines the exact time the plugs fire by de-energizing the driver circuit. With the coil primary ground circuit open, its magnetic field collapses and induces the high voltage in the secondary coil that causes the arc at the plug.

The logic module continuously updates the spark advance curve to achieve the best engine combustion process. This then provides maximum fuel economy, lower emissions, and the best possible driveability.

The spark advance curve in drive is based on a schedule that is stored in logic module memory. The logic module checks the inputs from the distributor, MAP, TP sensor, and CT sensor against the schedule before determining the correct amount of spark advancement to fit a given operating condition. Obviously, there will be different curves provided for a cold engine as well as engine operating at normal temperature and at all conditions in between.

The spark advance schedule used during park/neutral operation is dependent on a number of factors, including time since engine start, engine rpm, temperature of a cold engine, and idle error for a warm engine.

The spark timing is advanced on a cold engine and will begin to retard toward initial as the engine warms up. However, in many cases, a slightly advanced timing schedule is used on a warm engine to maintain a stable idle.

22-6 SINGLE-POINT EFI MODULES AND SYSTEM OPERATION

The single-point EFI system uses two control modules. These are the logic and the power.

Logic Module

The *logic module* is the digital microcomputer for the system. It contains a microprocessor and memory units and is located inside the vehicle behind the right-front kick pad (Fig. 22-35).

The logic module, in order to receive accurate input signals, sends a reference voltage of five volts to the MAP, TP, CT, and VS sensors, the latter via a resistor.

In operation, the logic module controls the operation of various devices either by providing a ground circuit through an internal output driver transistor or energizing or de-energizing one found in the power module. The devices controlled by the logic module include the injector solenoid, EGR solenoid, purge solenoid, AIS motor, and ignition system.

As mentioned, the logic module has the capability for self-diagnostics. If a fault is found in a monitored system or component, the logic module will set a code in memory and turn the power loss lamp on by providing it with a ground.

The code can be recalled at a later time by using one of two methods. First, a technician can cause the power loss lamp to flash the code. Second, he or she can read a numbered fault code by plugging a readout box into the diagnostic connector.

The logic module is programmed with an *adaptive memory*, which is similar to block learn and integrator programs in General Motors EFI computers. In any case, this makes the EFI system capable of compensating for changes in a number of sensor inputs as well as alterations in component tolerances due to wear.

This compensation is accomplished in closed loop operation only through the use of a variable signal to the pulse width output driver transistor. This signal is derived from the contents of one of twelve adaptive memory cells that are contained in the logic module. Ten of the cells have oxygen sensor, rpm, and MAP data stored, while two contain information on idle speeds in park, neutral, and drive. All twelve of these cells are stored in nonvolatile memory and are activated whenever power is connected to the logic module.

From the ten cells, the one that provides the actual pulse width signal is determined by the strengths of oxygen sensor, rpm, and MAP signals. In other words, the pulse width provided by a given cell reflects any changes in one or more or these input signals.

In addition, if either the rpm or MAP signals do not change as they should with alterations in engine speed or load, the memory cell that provided the pulse width before the problem occurred will continue to do so. However, if one of these signals changes along with the one from the oxygen sensor, the pulse width signal will usually be provided by a more updated cell. As a result, the memory cell can adapt somewhat to an irregular signal. The only exception to this is the oxygen sensor. If its signal does not change, the system drops back into open loop.

The logic module also provides a limp-in mode. For example, the complete loss of any one of the three major sensor inputs to the logic module cells will cause it to put the system into limp-in mode. Only a zero voltage reading from the MAP, TP, or CT sensor will initiate the limp-in mode.

No matter which sensor is at fault, the logic module will put the power loss lamp on and store a code for the malfunctioning component. Under these circumstances, the logic module substitutes one or more other sensor values for the malfunctioning unit. As a result, the engine will continue to operate, but not very efficiently.

Power Module

The *power module* (Fig. 22-36) mounts in the left-front fender well behind the battery. This remote location from the logic module is necessary for two reasons. First, it facilitates the airflow needed to cool the switching driver transistors. Second, the power supply for the ignition coil and injector circuits has been isolated to reduce electrical interference from reaching the logic module.

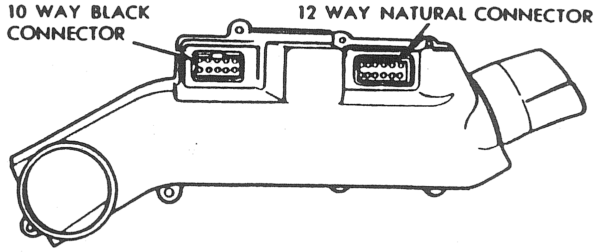


FIGURE 22-36
Power module. (Courtesy of Chrysler Motors Corp.)

The power module contains a converter that reduces battery voltage to a regulated eight-volt output. This voltage is then directed to the logic module and the Hall-effect switch within the distributor.

The power module also contains the ignition and injector drive circuits. These control the ground circuits for the ignition coil and injector via output commands sent from the logic module. In other words, the power module will only ground these circuits when told to do so by the logic module.

Another drive circuit within the power module controls the ground to the automatic shutdown relay. The ground only occurs after the module receives the appropriate signals from the distributor Hall-effect switch.

Automatic Shutdown Relay

The *automatic shutdown relay* is located inside the vehicle above the logic module. This unit and the fuel pump relay are the same component.

The relay itself controls the fuel and ignition systems. With the ignition switch in the start position and the engine cranking, the distributor directs a pulse signal to the power module. This grounds the relay, allowing battery voltage to be supplied to the fuel pump, logic module, ignition coil (+) terminal, and injector and ignition coil drive circuits within the power module.

If the power module, on the other hand, does not receive a distributor signal for a minimum of one-half second after the first pulse, or if an engine speed of at least 60 rpm is not indicated, then the power module breaks the relay ground circuit. This shuts down the fuel and ignition systems as a safety feature.

Single-Point EFI System Operation

As in the case of the EFC system, the logic module for EFI provides open and closed loop modes of operation. The EFI system will be in open loop during engine start-up, cold engine operation, idle or closed throttle deceleration, and wide-open throttle. It will also be in open loop until the oxygen sensor reaches a specified temperature and provides a reliable signal, and if the oxygen sensor signal does not change for a specific period of time.

Three conditions must be met before the logic module will put the system into closed loop. First, the coolant temperature must reach a specific value. Second, a specific period of time must have elapsed since engine start-up. Third, the oxygen sensor must be generating a valid signal to the logic module.

Operating Conditions

During operating conditions other than closed loop, light-load cruise, the engine's air/fuel ratio is determined as much by driveability and performance considerations as by emissions levels. Under these conditions, the programmed speed density pulse width signal is altered by modifier programs through the use of CT and TP sensor signal inputs.

Starting

During engine starting, the logic module controls the injector pulse width following a number of programs stored in memory. For example, during engine starting, the injector is pulsed four times per engine revolution rather than twice. The doubling of the pulses will continue until engine rpm exceeds a given value for a specific period of time. The pulse width is independent of all sensor inputs except for the CT sensor and a time factor since engine cranking was initiated. The programmed pulse width will be longer for a cold start as compared to a warm restart.

Cold Engine Operation

When the CT sensor signal indicates a less than normal operating condition, the pulse width is adjusted by an enrichment modifier program within one of the logic module memories. This program provides a longer pulse width for an enriched mixture. This produces reliable driveability, good performance, and the lowest emissions levels possible with a cold engine.

Closed Throttle Operation

With the throttle closed at normal idle, the airflow through the throttle body decreases. In response to MAP, TP sensor, and CT sensor signals, the module is programmed to reduce the injector pulse width to provide the proper air/fuel ratio at idle.

During a deceleration condition with a closed throttle, a special modifier program leans out the air/fuel mixture as engine rpm decreases. This intentional lean out condition throughout deceleration conserves fuel and decreases HC and CO emissions.

Acceleration Conditions

The logic module recognizes an abrupt increase in throttle position as a demand for additional engine output needed for vehicle acceleration. In this situation, an acceleration enrichment modifier program lengthens the pulse width to increase engine power. This provides reliable vehicle operation without engine hesitation or stumble.

Since an accurate MAP sensor signal cannot be obtained until air has entered the manifold through the opening throttle valve, the TP sensor signal is used to adjust the air/fuel ratio. The acceleration modifier program also uses the input signal from the CT sensor to compensate the pulse width for engine temperature.

Wide-Open Throttle Operation

At sustained wide-open throttle, the pulse width is again lengthened to enrich the air/fuel ratio. This ratio is needed to increase engine power output and prevent engine detonation damage resulting from elevated combustion chamber temperatures.

At wide-open throttle, the logic module uses a pulse width program based on the MAP signal. In other words, from normal acceleration to wide-open throttle, the pulse width is varied using first inputs from the TP and CT sensors to that from the MAP alone.

Idle Speed Control

To maintain the necessary idle speed under all conditions, the logic module uses a speed feedback program in all driving ranges. This controls the operation of the AIS motor.

However, in park and neutral, a spark advance compensation program is used by the module. This program applies a spark advancement variation that

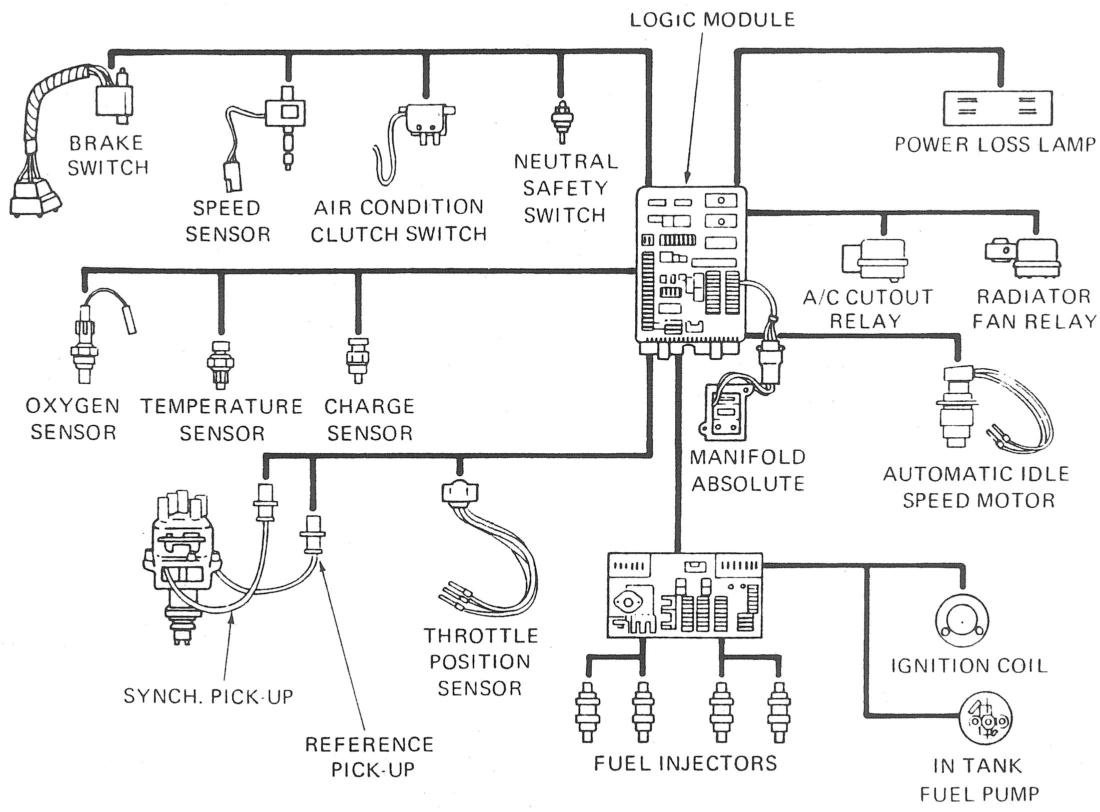


FIGURE 22-37
Multipoint EFI system.

is proportional to errors in idle speed. In other words, if the idle is too low, the program advances the spark timing to increase idle speed.

This spark variation is limited to no more than 12 degrees. If the speed error exceeds the specification with the maximum amount of spark advancement, the AIS motor is activated to change airflow through the auxiliary air passage.

To prevent the AIS motor from closing the air passage on deceleration, the logic module uses an input from the VS sensor to override the speed feedback program until the vehicle is at rest. Moreover, when the throttle is opened, the program triggers an AIS kick, which partially reopens the air passage in anticipation of a deceleration. The AIS motor position during deceleration helps to control HC and CO emissions and to prevent a die-out during panic stops.

The feedback program also increases idle speed during cold engine operation. This provides a safety margin against engine die-outs after cold start-ups and during the warm-up period.

22-7 MULTIPOINT EFI SYSTEM

The *multipoint EFI system* has nearly the same design and operates in much the same manner as its single-point counterpart. (Fig. 22-37). However, there are some design and functional changes to the sensor inputs, output devices, and the modules in the multipoint system.

Sensor Inputs

One of the changes to the logic module inputs is the addition of a charge temperature sensor. This sensor has the same design and function as the one found in the EFC system. That is, it develops a signal to the logic module based on the temperature of the air/fuel mixture within the intake manifold.

The other input change is to the distributor sensor. In the multipoint system, the Hall-effect reference signal is sent only to the logic module. In addition, the distributor has a second Hall-effect switch (SYNCH pickup) installed beneath the other.

This second Hall-effect switch has a shutter wheel with a single vane instead of four. The one vane, however, occupies 180 degrees or one-half of the shutter wheel. With this design, the leading and trailing edges of the vane each provide a signal to both the logic and power modules.

The power module uses this signal to deter-

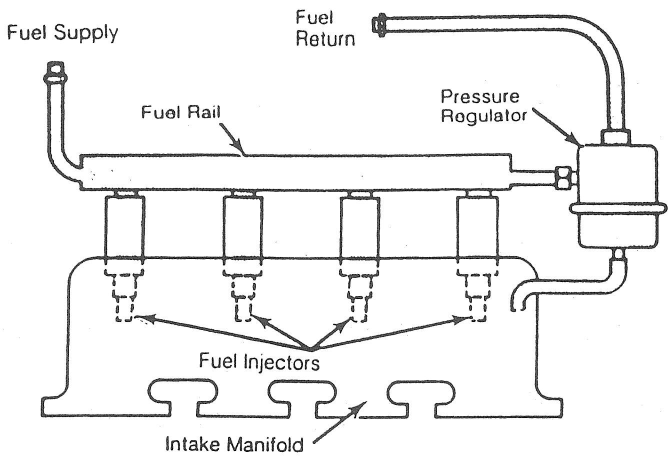


FIGURE 22-38
Fuel injectors and rail.

mine which pair of injectors (one and two, or three and four) to energize after receiving the on signal from the logic module. The logic module utilizes the signal along with other sensor data to determine pulse width.

Outputs

The only change to the system output devices is the addition of more injectors. These are installed between the intake manifold and a fuel rail, as shown in Fig. 22-38. Two of these injectors are pulsed simultaneously. The logic and power modules pulse one pair during the first revolution of the engine cycle and the other two during the second.

Logic and Power Modules

The only change to the modules is the programming. Both are programmed to pulse the additional injectors as described above. Other than this, the modules operate the system in much the same way as their counterparts for single-point injection.

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete the statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. Describe the main differences between the single-point and multipoint EFI systems [22-7].
2. Why is microcomputer temperature compensation important [22-1]?
3. Why is the logic module separated from the power module [22-6]?
4. How does the EFC microcomputer control ignition timing [22-2]?
5. Describe how the EGR solenoid controls exhaust gas recirculation in the EFC system [22-5].
6. What are the names and locations of the EFC computer [22-3]?
7. Name the switches that provide input signals into the EFI logic module [22-4].

REVIEW

1. During one crankshaft revolution, how many multipoint injectors are pulsed [22-7]?
   1. one
   b. two
   c. three
   d. four
2. The three-terminal EFC's coolant temperature (CT) sensor has one element that controls only the operation of [22-1]
   a. canister purge.
   b. spark advance.
   c. EGR solenoid.
   d. fan relay.
3. What new input signals are needed by the multipoint EFI that single-point systems did not require [22-7]?
   a. charge temperature switch
   b. SYNCH pickup
   c. both a and b
   d. neither a nor b
4. On an eight-cylinder EFC system, what type of distributor sensor is used [22-1]?
   a. dual pickup coil
   b. single pickup coil
   c. single Hall-effect switch
   d. dual Hall-effect switch

5. Why is the AIS motor energized to increase idle speed during deceleration [22-6]?
   a. to reduce HC emissions
   b. to reduce CO emissions
   c. to prevent engine die-out on panic stops
   d. all of these

6. Which EFC sensor monitors engine load [22-1]?
   a. MAP
   b. TP
   c. vacuum transducer
   d. CT

7. What EFI sensor controls pulse width at wide-open throttle [22-6]?
   a. CT
   b. MAP
   c. distributor
   d. both a and b

8. Which sensor is the piezoelectric type [22-1]?
   a. Hall-effect pickup
   b. CT
   c. vacuum transducer
   d. detonation

9. Which sensor signal energizes the EFI's ASD relay [22-6]?
   a. distributor
   b. TP
   c. MAP
   d. CT

10. An oxygen feedback solenoid controls how many carburetor circuits [22-2]?
    a. one
    b. two
    c. three
    d. four

11. The EFI adaptive memory can compensate for [22-6]
    a. changes in component tolerances.
    b. changes in engine load.
    c. changes in exhaust gas oxygen content.
    d. all of these.

12. How many times per second does the EFC computer turn the feedback solenoid on and off [22-2]?
    a. ten
    b. eight
    c. six
    d. four

13. In using the speed density approach to determining pulse width, the logic module uses input signals from [22-5]
    a. the MAP sensor.
    b. the distributor.
    c. both a and b.
    d. neither a nor b.

14. The EFC computer did not have built-in self-diagnostic capabilities before [22-2]
    a. 1985.
    b. 1983.
    c. 1981.
    d. 1979.

15. When will the power loss lamp come on [22-5]?
    a. when a code is set in memory
    b. when the logic module detects a problem in a given circuit
    c. when the ignition switch is turned on
    d. all of these

16. What part of the combustion control computer is software [22-3]?
    a. PROM
    b. ROM
    c. RAM
    d. all of these

17. How does the AIS motor control idle speed [22-5]
    a. by moving the throttle linkage
    b. by rotating the throttle shaft
    c. by controlling the airflow through a bypass channel
    d. by acting as a throttle stop

18. Which EFC-controlled engine will not go into closed loop at idle [22-3]?
    a. six-cylinder
    b. eight-cylinder
    c. four-cylinder
    d. all of these

19. Which input causes the logic module to alter idle speed relative to gearshift selector lever position [22-4]?
    a. VS sensor
    b. park/neutral safety switch
    c. brake switch
    d. A/C clutch switch

20. In the EFI system, which sensor monitors atmospheric pressure [22-4]?
    a. TP
    b. MAP
    c. CT
    d. vacuum transducer

Chapter 23

TESTING A TYPICAL CHRYSLER EFC AND EFI SYSTEM

OBJECTIVES

After reading and studying this chapter, you will be able to

- define a driveability test procedure and know how it functions.
- identify the tools and test equipment necessary to test EFC and EFI systems.
- demonstrate how to use a diagnostic readout box.
- explain the steps of a diagnostic testing procedure.
- perform a system visual inspection.
- follow the diagnostic procedures for a no-start condition.
- follow the diagnostic procedures for a driveability complaint.

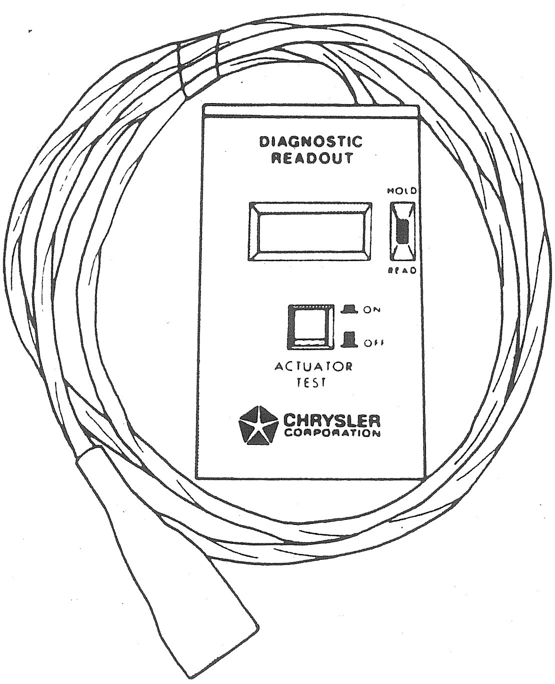


FIGURE 23-1
Diagnostic readout box. (Courtesy of Chrysler Motors Corp.)

The basic diagnostic test procedures for the post-1985 EFC and the post-1984 EFI systems are nearly the same. Of course, there have to be a number of differences due to the fact that the EFC is carbureted and the EFI has one or more fuel injectors. Enough of the basic steps are the same, however, that this chapter can cover just the EFC to cut down on repetition. Keep in mind that the procedures presented are just a sampling to familiarize you with the procedure. *Always follow the procedures outlined in either the driveability test procedure manual or those in the vehicle service manual. Otherwise, you may replace or damage serviceable components.*

Before attempting to test an EFC system, there are a few important facts you must remember. First, *always assume that the problem is not within the EFC system.* As mentioned many times before, the majority of no-start and driveability problems are due to simple things that technicians have dealt with for years like a defective spark plug, high tension cable, distributor cap, or rotor. Even a simple thing like a leaking or disconnected vacuum hose or a corroded electrical terminal can cause multiple driveability problems.

Second, if the spark control or combustion control computer stores a trouble code, *do not assume that it or one of the EFC components is at fault.* The real cause of the malfunction may, in fact, be one of the simple problems listed above.

23-1 DRIVEABILITY TEST PROCEDURES DEFINED

Driveability test procedures are a systematic method of checking the function of certain engine control systems to determine if they are operating satisfactorily. When a given control system is found to be malfunctioning, the procedure also provides a systematic method of locating the cause of the problem. The test procedures are also designed to use all the built-in features of on-board computer diagnostics to pinpoint the problem in the shortest possible time.

The driveability test procedures are designed to work because they adhere to the following three basic principles:

1. They form a system approach to diagnosis. There are many engine control systems that affect vehicle driveability. All of these work together as a team. However, if any one system malfunctions, a driveability problem occurs. Therefore, any system that can cause a driveability problem is part of the test procedure.

2. They test interrelated engine control systems. Since there are so many systems, all must be evaluated to check their effect on each other. This is especially true if one system is malfunctioning, and it causes another to do so also. The driveability test procedures will check all engine systems in a given sequence one at a time. Therefore, you will only see and evaluate the results of one system test at a time. Sometimes you will not need to check a given engine system. If the on-board diagnostic system monitors a given system and no code has been set for it, there is no need to test it. However, if any part of a system's function is not monitored, it may be defective, and a code will not be set. In this case, a test procedure will have to be followed to locate the problem. There can be some failures that produce certain fault code combinations. In this case, the diagnostic test procedures will be very specific on what the problem is.

3. The procedures check the driveability problem under the same circumstance it occurred. Many of the engine control systems operate differently cold than they do at normal operating temperature. In order to diagnose a cold driveability problem, the engine has to be cold. The same applies for malfunctions that occur at normal operating temperature. Therefore, there are driveability test procedures for problems that occur with the engine cold and with it at normal operating temperature.

23-2 TOOLS AND TEST EQUIPMENT NEEDED TO PERFORM DIAGNOSTIC TESTS

To diagnose Chrysler systems, you will need a number of tools and pieces of test equipment. The items required include a digital volt/ohmmeter, jumper wires, a hand-held vacuum pump, a tachometer, a power timing light, a vacuum gauge, an oscilloscope, a two- or four-gas exhaust analyzer, and a scan tool or C-4805 diagnostic readout box. All of these items are discussed in Chapter 5. However, since the emphasis of this chapter is on Chrysler systems, let's examine in more detail the function of the C-4805 readout box and how to use it.

Functions of the Readout Box

The *diagnostic readout box* (Fig. 23-1) is used to put the computer into one of three test modes. These are the diagnostic test mode, a circuit actuation test mode, and a switch test mode. These three modes of testing are called for at different intervals when using the driveability test procedures. Without the readout box or an equivalent scan tool, you will not be able to put the computer into any of the modes.

The *diagnostic test mode* is used to check and see if there are any fault codes stored in the computer's diagnostic memory. The *circuit actuation test mode (ATM test)* is utilized to turn a specific circuit on and off in order to test it. ATM test codes are used during this mode. The *switch test mode* is used to determine if specific switch inputs are being received by the microcomputer.

Using the Diagnostic Readout Box

To use the readout box to put the computer into one of the three test modes, follow the instructions outlined below:

Diagnostic Mode

1. Plug the connector of the readout box into the mating connector in the underhood wiring harness (Fig. 23-2).

2. Position the read/hold switch on the readout box into the read position.

3. Open the carburetor switch by placing the fast idle speed adjusting screw on the highest step of the fast idle cam.

4. Turn the ignition switch on and wait for 00 to appear on the readout box display.

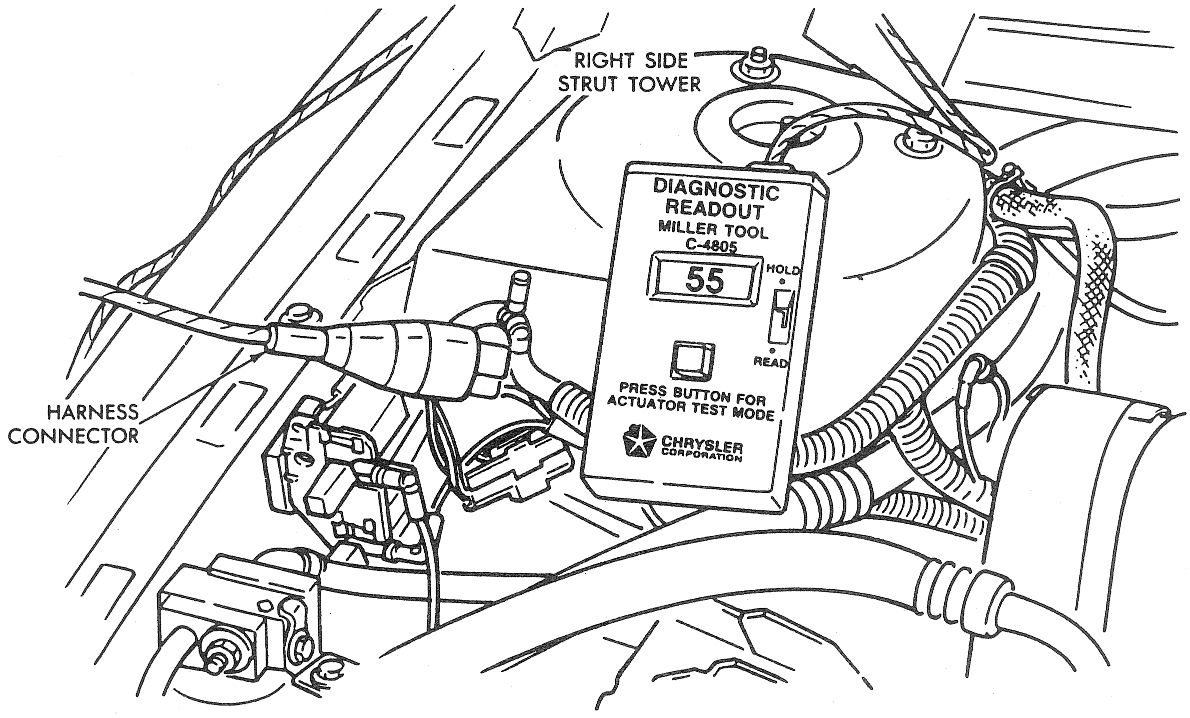


FIGURE 23-2
Using the readout box. (Courtesy of Chrysler Motors Corp.)

5. Move the read/hold switch to the hold position.

6. Read and record all codes.

Note: You may stop the code displays by moving the switch to the read position. The codes will begin displaying again if you return the switch to the hold position.

ATM Test

1. Put the diagnostic system into the test mode and wait until Code 55 appears on the readout display.

2. Press and hold down the ATM button on the readout box until the desired ATM test code appears on the display. Release the button.

3. The computer will turn the selected circuit on and off at 250-millisecond intervals for five minutes, and then turn the test off. However, you can stop the test at any point by turning the ignition switch off.

Switch Test Mode

1. Place the system into the diagnostic test mode and wait until Code 55 appears on the readout window.

2. Make sure all switches that send an input to the computer are now turned off.

3. Press the ATM button in and immediately move the read/hold switch to the read position.

4. Wait until 00 appears on the readout window.

5. Turn on the desired switch so it can provide input into the computer.

6. If the input signal is received by the computer, the display will change to 88 when the switch is on, and then back to 00 after the switch is turned off.

Fault Codes

Fault codes are two-digit numbers that identify a circuit monitored by the computer during self-diagnosis. A fault code will be set into computer memory if the assigned circuit malfunctions.

The charts in Figs. 23-3 and 23-4 provide such information as a complete list of fault codes, the engines the codes apply to, what circuits the codes apply to, and what will cause the code to be placed in computer memory.

In most cases, a fault code will not identify the component in the circuit that is defective. Therefore, the code is only the effect and not necessarily the cause of the problem. However, due to the design of the driveability test procedures, the code may represent the cause of the problem. For this reason, it is important that the test procedures be followed in order to understand just what the fault code is trying to tell you.

ATM Test Codes

Also notice in Figs. 23-2 and 23-4 the *ATM test codes*. These are two-digit numbers that identify various circuits that you will use during diagnostics. For instance, during the ATM test mode, if Code 91 is selected, the computer energizes and de-energizes the carburetor oxygen feedback solenoid. A Code 93 will cause the computer to turn the canister purge solenoid on and off and so forth.

General Testing and Service Tips

Before attempting to perform actual no-start and driveability test procedures, you should review and follow the general safety precautions outlined in Chapter 5. In addition, listed below are some other general testing and service guidelines you must adhere to when working on the Chrysler systems.

1. Never use a test light in place of a digital voltmeter.

2. The vehicle being tested must have a fully charged battery.

3. At the end of each test procedure, turn the ignition switch off, reconnect all disconnected wires and hoses, and reinstall any components that were removed for testing.

4. Each no-start or driveability test procedure is made up of a number of tests. Always start at the first test of the procedure. Starting at any other test will only give incorrect results.

5. Each test may have many steps listed. Only perform the steps indicated under the ACTION REQUIRED COLUMN. It is not necessary to perform all the steps in a test unless told to do so. If you do,

Code	Type	Engine	Circuit	When Monitored By The Computer	When Put Into Memory	ATM Test Code
11	Fault	1.6 - 2.2	Carburetor O_2 Solenoid	All the time when the engine is running.	If the O_2 solenoid circuit does not respond to computer commands.	91
12	Not Used				Disregard this code.	
13	Fault	2.2	Canister Purge Solenoid	All the time when the engine is running.	If the canister purge solenoid circuit does not turn on and off at the correct time.	93
14	Indication	1.6 - 2.2	Battery Feed for Computer Memory	All the time when the ignition switch is on.	If the battery was disconnected within the last 20-40 engine starts.	None
16	Not Used				Disregard this code.	
17	Fault	2.2	Electronic Throttle Control Solenoid	All the time when the engine is running.	If the throttle circuit control solenoid does not turn on and off at the correct time.	97
18	Fault	2.2	Vacuum Operated Secondary Control Solenoid (V.O.S.)	All the time when the engine is running.	If the V.O.S. control solenoid circuit does not turn on and off at the correct time.	98
21	Fault	1.6 - 2.2	Distributor Pickup Coil	During engine cranking.	If there is no distributor signal input at the computer.	None
22	Fault	1.6 - 2.2	Oxygen Feedback System	All the time when the engine is running in closed loop operation.	If the oxygen feedback system stays rich or lean longer than 5 minutes.	None
24	Fault	1.6 - 2.2	Computer	All the time when the engine is running.	If the vacuum transducer fails.	None
25	Fault	2.2	Radiator Fan Temperature Sensor	All the time when the engine is running.	If the engine temperature sensor circuit indicates 100°F or less and the radiator fan temperature does not agree or changes too fast to be real.	None
26	Fault	1.6 - 2.2	Engine Temperature Sensor	All the time when the engine is running.	If the engine temperature sensor circuit does not read 100°F after 30 minutes from when the engine started. Also, if the circuit is shorted or changes too fast to be real.	None
28	Fault Manual Trans Only	1.6 - 2.2	Speed Sensor	During vehicle deceleration from 2000 to 1800 rpm for 3 seconds, engine temperature above 150°F and vacuum above 21.5 inches.	If speed sensor circuit does not indicate between 2 and 150 mph.	None
31	Fault	1.6 - 2.2	Battery Feed for Computer Memory	All the time when the ignition switch is on.	If the engine has not been cranked since the battery was disconnected.	None

FIGURE 23–3
EFC fault codes. (Courtesy of Chrysler Motors Corp.)

the problem will not be found. Moreover, some steps may have reminders. These are to let you know that some previous instructions must still be followed.

6. To perform a cold driveability procedure, the engine must not be started for at least seven hours.

7. To perform a warm driveability procedure, the engine must be at normal operating temperature.

Code	Type	Engine	Circuit	When Monitored By The Computer	When Put Into Memory	ATM Test Code
32 33	Fault	1.6 - 2.2	Computer	Upon entry into the diagnostic mode.	If computer fails.	None
55	Indication	1.6 - 2.2			Indicates end of diagnostic mode.	None
88	Indication	1.6 - 2.2			Indicates start of diagnostic mode. **NOTE:** This code must appear first in the diagnostic mode or fault codes will be inaccurate. Indicates switch is on in switch test mode.	None
00	Indication	1.6 - 2.2			Indicates that the diagnostic readout box is powered up. Indicates switch is off in switch test mode.	None

FIGURE 23-4
EFC fault and diagnostic codes. (Courtesy of Chrysler Motors Corp.)

23-3 TEST CATEGORIES

Test procedures for Chrysler systems are made up of three problem categories, no-start, cold driveability, and hot driveability. It is not necessary to perform the procedures set forth for each problem category. The selection of what process to use will be determined by the description of and when the problem occurred.

At this point, it is not necessary to worry about the actual problem symptom. Since one or more of the engine control systems can produce the same symptom, it is more important to find out when and how often the engine does not operate correctly.

For each problem category, there are test procedures listed either in the vehicle service manual or a driveability test procedure booklet. Listed below are the three problem categories and the basic procedural steps that should be followed. The last four sections of this chapter will discuss the actual process in more detail.

1. Engine will not start
   a. Perform a visual inspection.
   b. Follow no-start test procedures.
2. Cold driveability problem
   a. Perform a visual inspection.
   b. Oscilloscope the engine to check ignition system operation.
   c. Perform exhaust gas analysis to check engine mechanical condition and fuel system operation.
   d. Follow the cold driveability test procedures.
3. Warm driveability problem

Perform the same steps as listed above under the cold driveability problem.

23-4 VISUAL AND OPERATIONAL CHECKS

In all of the three test categories mentioned above, the first step is always a thorough underhood inspection. The importance of this inspection cannot be emphasized enough because many of the causes of no-start or driveability problems can be found during this first step. For this reason, never pass it up.

During the underhood inspection, you will basically be looking for problems within electrical wiring and connectors, plus deteriorated, leaking, or disconnected vacuum hoses. Any problems in any of these can cause malfunctions in either the ignition or fuel systems.

Electrical Components

In regard to electrical components, inspect all wires

for signs of the insulation being chafed through, cut, or burned. Any of these problems can cause a short circuit. Look for loose wiring connectors or those that are not fully plugged into each other, or for terminals that are not fully installed into the insulator. Also, make sure that all EFC system connectors lock together.

With these facts in mind, let's look at the actual locations where you must check for the abovementioned problems.

1. Ignition system components
   a. Connectors at the computer
   b. Pickup coil connector at the distributor
   c. Spark plug wires and terminals
   d. Coil to distributor cap high tension cable
   e. Coil wiring connections
   f. Starter relay wiring connections
2. Fuel control system
   a. Feedback solenoid connector
   b. Coolant sensor connector
   c. Choke connector
   d. Carburetor idle switch connector
   e. Oxygen sensor connector
   f. Oxygen sensor test connector
   g. Computer ground at left fender shield
   h. Speed sensor connector
3. Vehicle electrical system
   a. Battery cables
   b. Battery ground to engine
   c. Engine to main harness connectors
   d. Engine to firewall ground strap

Hoses

When inspecting all hoses, check them for signs of deterioration or to see if they are pinched or cut. Also, check all hoses to see if they are fully and firmly connected onto their correct fittings. Use either the diagram on the underhood emission label or the one found in the vehicle service manual to check for correct hose routing (Fig. 23-5).

You should check for these problems at the following locations:

1. PCV system
   a. Hose between PCV valve and intake manifold
   b. Hose between air cleaner and breather module
2. Computer
   a. Air intake hose
   b. Hose between carburetor and vacuum transducer
3. EGR system
   a. Hose between the carburetor and the EGR solenoid
   b. Hose between the solenoid and the EGR valve
4. Air switching system
   a. Hose between the carburetor and the air switching solenoid
   b. Hose between the solenoid and the air switching valve
   c. Hose between the air pump and air switching valve
   d. Hose between the air switching valve and exhaust manifold
   e. Hose between the air switching valve and catalytic converter plumbing
5. Evaporation control system
   a. Hose between the carburetor and external bowl vent valve
   b. Hose between the external bowl vent valve and the canister
   c. Hose between the external bowl vent valve and the air switching valve
   d. Hose between the canister and purge solenoid
   e. Hose between the purge solenoid and the plastic tee of the EGR signal hose
   f. Hose between the canister and the carburetor spacer
6. Choke system
   a. Hose between the carburetor and the plastic connector
   b. Hoses between the three-way connector and the choke pull off and heater air door sensor

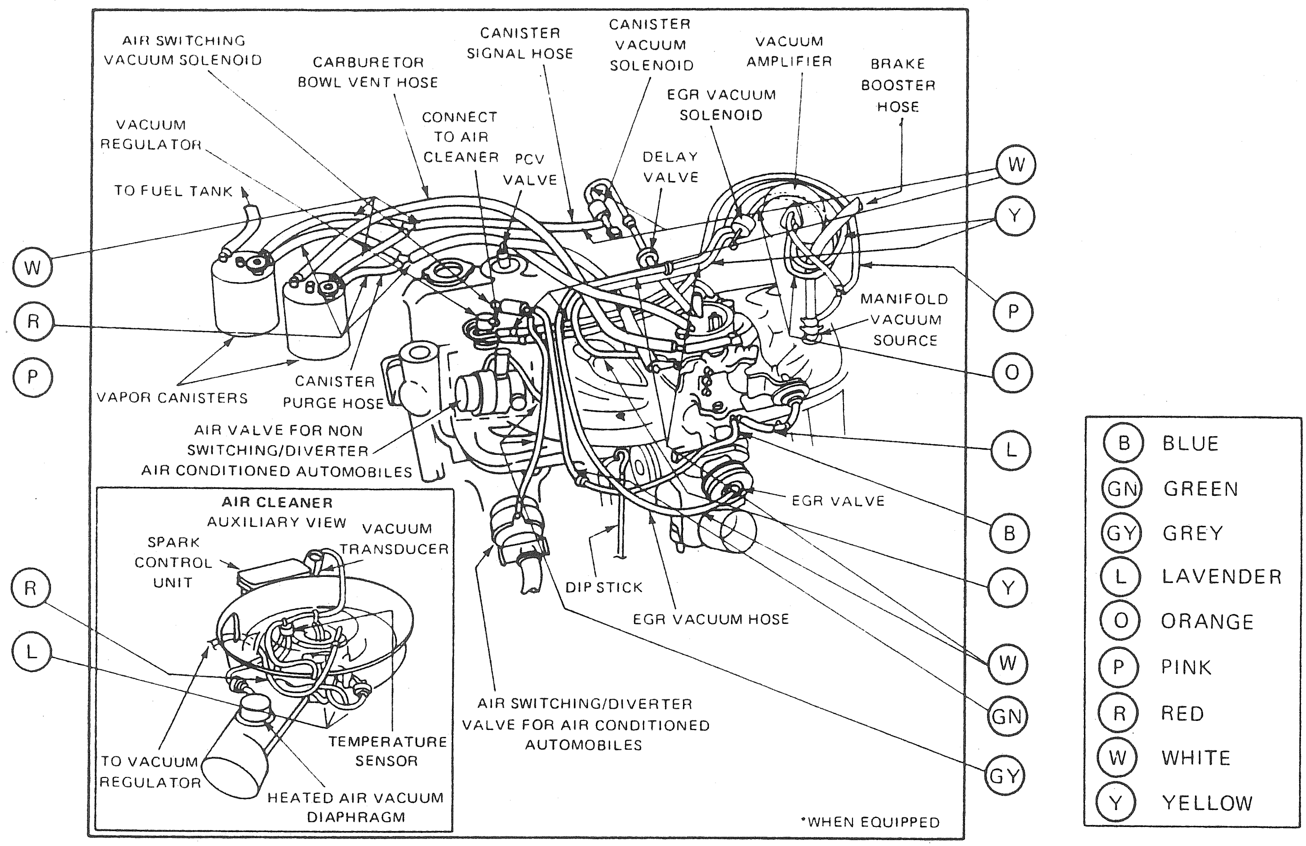


FIGURE 23-5
Typical vacuum hose routing diagram.

7. Heated air door system
   a. Hose between the air sensor and delay valve
   b. Hose between the delay valve and door motor
   c. Hose between the air cleaner and the exhaust manifold heat stove

Operational Checks

Whenever there is a cold or warm driveability complaint, you should always perform operational checks of the ignition and fuel systems using an oscilloscope and an exhaust analyzer. As mentioned, any problems within either of these two systems will cause a driveability problem. Furthermore, a malfunction within either system can interfere with the signal from the oxygen sensor, which will make the computer either leanout or enrich the air/fuel mixture when it should not do so. A malfunction in one of these systems could even cause the computer to set a Code 22 into memory.

For these reasons, use the oscilloscope to check primary and secondary circuit operation; spark plugs for fouling or misfires; secondary circuit for high resistance; spark plug cables for opens, shorts, or grounds; ignition timing; power output of each cylinder; and alternator output.

Use the exhaust gas analyzer to check a high HC reading that could result from a vacuum leak, low compression, or defective air pump or catalytic converter; a high CO reading that could result from a rich mixture, clogged air cleaner, stuck choke, or defective air pump or catalytic converter; and high or low oxygen readings due to a lean or rich air/fuel mixture.

23-5 PROCEDURES FOR A NO-START CONDITION

This procedure deals with the common problem of an engine that cranks over but will not start. In this situation, you should, as mentioned, always perform

TEST 1	STEP A	CHECKING FOR SPARK AT SPARK PLUG WIRES	
PROCEDURE		TEST INDICATION	ACTION REQUIRED
• Remove any spark plug wire and insert an insulated screwdriver in terminal. • Hold screwdriver shaft near (¼") a good ground. • Have someone crank engine.		• There should be good spark between the screwdriver and ground.	• Spark okay, **Perform Fuel TEST NO. 2.**
			No spark, **Perform TEST NO. 5.**

FIGURE 23–6
Test 1 of the no-start diagnostic procedures. (*Courtesy of Chrysler Motors Corp.*)

the underhood inspection. If you do not locate the cause of the problem, then proceed to the no-start test procedures. These will be located either in the vehicle service manual or a driveability test procedure booklet.

Figures 23–6 and 23–7 illustrate the first two no-start tests for a typical EFC system. In all, there are seven tests, some of which have a number of steps. Obviously, the starting point of the process begins with Test 1.

Test 1 (Fig. 23–6) is typical of all the no-start procedures. At the top of the test itself is information that identifies the test number, step, and what the procedure is checking for. Below this are column headings entitled procedure, test indication, and action required. Under the procedure heading is the actual step-by-step testing process you must follow. In the case of Test 1, the procedure instructs you how to check for an arc at any spark plug wire.

Note: You can substitute a spark tester during this process.

The test indication column provides the results you should expect as a result of the procedure followed.

The action required column provides you with important directions. Using the results of the procedure as a guide, this column then guides you to the next test procedure to follow. Notice, the first action tells you to proceed with Test 2, while the second tells you to proceed to Test 5.

Notice that Test 2 (Fig. 23–7) follows the same format, as do all the no-start procedures. The key to being successful is to perform the procedure outlined completely and then take the required action. As shown in both of the action required columns of Tests 1 and 2, you may not have to perform all the

TEST 2	STEP A	CHECKING FOR FUEL IN CARBURETOR	
PROCEDURE		**TEST INDICATION**	**ACTION REQUIRED**
• Remove air cleaner cover. • Move throttle linkage by hand several times. • Look for fuel spray from accelerator pump nozzle in carburetor throat.		• There should be fuel spraying from the accelerator pump nozzle.	• Fuel spray okay, **Perform TEST NO. 3.**
			• No fuel spray, **Perform TEST NO. 7.**

FIGURE 23-7
Test 2 of the no-start diagnostic procedures. (*Courtesy of Chrysler Motors Corp.*)

tests to locate the cause of the problem. Moreover, in the tests with multiple steps, you may not have to perform all of them. In other words, to be successful in finding the cause of the problem, just follow the test instructions carefully and completely.

23-6 DRIVEABILITY TEST PROCEDURES

A *driveability test procedure* is used to locate the cause of engine operating problems other than no-start. However, as in the case of the no-start process, you always begin with the underhood inspection. If no problems are discovered during the inspection, complete the operational checks as described earlier. If the ignition and fuel systems are functioning satisfactorily, proceed to driveability Test 1 (Fig. 23-8). Notice in the example that the test format is the same as that for its no-start counterpart just described.

In the case of driveability Test 1, the procedure instructs you to do a number of things, which include connecting the readout box into the system, performing the diagnostic test and recording all fault codes, erasing all fault codes from memory, running the engine for two minutes, and rechecking for any stored fault codes. This last step verifies if the fault still exists in the system or was intermittent.

The test indication column, in this test, provides results in the form of diagnostic and fault codes. Notice, for example, the first indication of 88-14-55. The meaning of this indication is as follows (see Figs. 23-3 and 23-4):

- 88 is a code representing the beginning of the diagnostic mode.
- 14 is an *indication code* that tells you a certain sequence of conditions has occurred. In this case, the codes tell you that the battery was disconnected from the computer to erase its memory of previous fault codes.
- 55 is a code representing the end of the diagnostic mode.

TEST 1 | STEP A | CHECKING SYSTEM FOR FAULT CODES

PROCEDURE

- Connect the diagnostic readout box to the engine harness connector.
- Put the system into the **Diagnostic Mode** (refer to Introduction).
- **Record all codes.**

NOTE: If fault codes 22, 28, 25 or 26 appear at this time proceed to test indication.

- Turn the ignition switch off and disconnect the computer 14-way connector for one minute and then reconnect it.
- Disconnect the diagnostic readout box.
- Start the engine and let it run for **two minutes.**
- Turn the engine off.
- Reconnect the diagnostic readout box.
- Put the system into the diagnostic mode.
- **Record all codes.**

If the same code appears before and after the engine is started, the problem still exists. Proceed to test indications.

If a code does not reappear after the engine is started, the problem no longer exists but was intermittent. Check for loose or corroded wiring connections in the circuit. Use wiring diagram as a guide.

TEST INDICATION	ACTION REQUIRED
88-**14**-55	• If a cold problem, **Perform TEST NO. 10.** • If a warm problem, **Perform TEST NO. 18.**
88-**11**-**14**-55 88-**11**-**14**-**22**-55	**Perform TEST NO. 2.**
88-**13**-**14**-55	**Perform TEST NO. 3.**
88-**14**-**17**-55	**Perform TEST NO. 4.**
88-**14**-**18**-55	**Perform TEST NO. 5.**
88-**14**-**22**-55	**Perform TEST NO. 6.**
88-**14**-**24**-55	Replace computer.
88-**14**-**25**-55 88-**14**-**26**-55	**Perform TEST NO. 7.**
88-**14**-**25**-26-55	Repair ground wire of engine coolant sensor for open circuit to the computer.
88-**14**-**28**-55	**Perform TEST NO. 8.**
88-**14**-**32**-55 88-**14**-**33**-55 88-**11**-**13**-**14**-**16**-**17**-**18**-55	Replace computer.
88-**13**-**14**-**17**-55	Repair ignition switch feed wire to dual solenoids for an open circuit.
No code **88** after switch is moved to the hold position.	**Perform TEST NO. 9.**
No code **00**	Check the diagnostic readout connector ignition and ground wire for open circuits. If okay repair the readout box.

FIGURE 23-8
Test 1 of the driveability procedures. *(Courtesy of Chrysler Motors Corp.)*

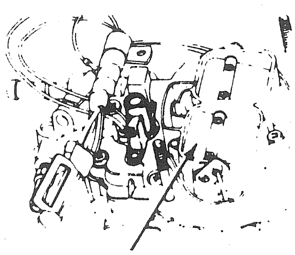
TEST 10	STEP A	CHECKING CHOKE AND FAST IDLE CAM LINKAGE	
PROCEDURE		TEST INDICATION	ACTION REQUIRED
• Set the accelerator linkage to the proper start position. • Remove the air cleaner. • Check the choke plate and fast idle cam position.		• Choke plate should be in fully closed position and fast idle screw should be on the highest step of the fast idle cam.	• Choke and cam position okay, **Perform TEST NO. 11.** • Choke not fully closed or cam not in position, check for choke plate sticking or binding. Repair choke and linkage as required.

FIGURE 23-9
Test 10 of the driveability procedures. (*Courtesy of Chrysler Motors Corp.*)

Notice the two numeral sequences in the second block under the test indication column. As in all cases, they both begin with 88 and end with 55. In between are either the indicator or fault codes. There may be a number of these codes displayed. However, the codes having the digits of the lowest value will appear first, such as 11 before 14 in the first sequence, and 14 in front of 22 in the second.

The directions within the action required column again tell you what test to go to, based on the codes received during the procedure. The first action shown in Fig. 23-8, for example, is for a cold problem, and it directs you to Test 10 (Fig. 23-9). The second action is a warm problem, and Test 18 must be used (Fig. 23-10). Notice that in both Tests 10 and 18 there is an illustration to assist you with the procedure.

To be successful in using the driveability test procedures, always remember to begin with Test 1 and then follow the directions. If the instructions tell you to skip over a test or step, make sure to do so. Otherwise, you may not find the cause of the problem or you may replace a serviceable part.

23-7 TESTING EFC SYSTEMS WITHOUT SELF-DIAGNOSTIC CAPABILITY

As mentioned earlier, pre-1985 EFC system computers did not have built-in self-diagnostics. Obviously, there will be no stored fault codes for these systems, and the diagnostic readout box cannot be used either to activate components or test switch inputs.

Diagnosis on these early models is divided into three stages: (1) verifying the complaint, (2) doing a visual inspection and operational check (for driveability problems only), and (3) performing Test 1 of the no-start or driveability test procedures.

The no-start and the cold and warm driveability test procedures are found in the vehicle service manual or test booklet. The format of both are about the same as that described in the last section. However, the driveability procedures do not contain fault codes to direct you to which test to perform. Instead, they will use problem symptoms as a guide to which test to use.

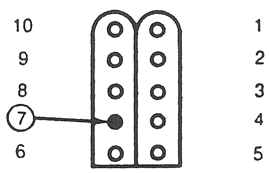
TEST 18	STEP A	CHECKING CARBURETOR SWITCH	
PROCEDURE		**TEST INDICATION**	**ACTION REQUIRED**
• Disconnect the computer 10-way connector. • Connect an ohmmeter between cavity No. 7 of the 10-way connector and ground. • Open and close the throttle while looking at the ohmmeter.	 COMPUTER 10-WAY CONNECTOR	• Ohmmeter should show continuity with no resistance when the throttle is closed and no continuity when the throttle is open.	• Continuity checks okay, **Perform TEST NO. 19A with 1.6L — TEST NO. 19B with 2.2L.**
			• No continuity with the throttle closed, repair the wire of cavity No. 7 for an open circuit to the carb switch.
			• Continuity with resistance with the throttle closed, clean the corrosion from the carb switch.
			• Continuity with the throttle open, repair the wire of cavity No. 7 for a short to ground.

FIGURE 23–10
Test 18 of the driveability procedures. (*Courtesy of Chrysler Motors Corp.*)

CHAPTER REVIEW

The following two sections will assist you in determining how well you remember the material contained in this chapter. If you cannot complete a statement or question, refer back to the section marked in brackets that contains the material.

SELF-CHECK

1. How does the diagnostic process differ on a pre-1985 EFC system [23-7]?
2. What is a driveability test procedure [23-1]?
3. What is always the second step in diagnosing a driveability complaint [23-6]?
4. Name and briefly describe the three readout box test modes [23-2].
5. What is the key to being successful in using the no-start test procedures [23-5]?
6. What determines which category of test procedure to use [23-3]?
7. Why is the underhood inspection so important [23-4]?

REVIEW

1. On pre-1985 EFC systems, what determines which driveability test procedure to use [23-7]?
   a. fault code
   b. indicator code
   c. underhood inspection
   d. complaint symptom

2. Technician A says if a monitored system does not set a fault code, there is no reason to test it. Technician B says if a system does not set a fault code, there still may be a problem in one of its unmonitored components.
   Who is correct [23-1]?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
3. Driveability test procedures must be followed [23-6]
   a. to locate the cause of engine operating problems.
   b. to locate the cause of a no-start condition.
   c. both a and b
   d. neither a nor b
4. To read the fault codes on the readout box [23-2],
   Technician A says push and read/hold button to hold.
   Technician B says push the read/hold button to read.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
5. Technician A says all driveability tests must be followed.
   Technician B says only specified driveability tests must be followed.
   Who is correct [23-6]?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
6. What code will the readout display when an input switch is turned on [23-2]?
   a. 55
   b. 15
   c. 00
   d. 88
7. A malfunctioning carburetor can cause a Code [23-4]
   a. 25.
   b. 22.
   c. 55.
   d. 88.
8. Before performing a cold driveability test procedure, allow the engine to cool for ____________ hour(s) [23-2].
   a. seven
   b. five
   c. three
   d. one
9. When should you perform the operational checks [23-4]?
   Technician A says before the no-start test procedures.
   Technician B says before the driveability test procedures.
   Who is correct?
   a. A only
   b. B only
   c. both a and b
   d. neither a nor b
10. What is the first step in any EFC diagnostic procedure [23-3]?
    a. operational check
    b. road test
    c. underhood inspection
    d. diagnostic mode test

REVIEW QUESTION ANSWER KEY

CH. 1

1. d
2. a
3. c
4. b
5. a
6. c
7. a
8. b
9. d
10. b

CH. 2

1. b
2. a
3. d
4. d
5. a
6. c
7. b
8. b
9. d
10. a
11. b
12. d
13. c
14. a
15. b
16. d
17. b
18. a
19. c
20. b

CH. 3

1. a
2. b
3. b
4. a
5. d
6. b
7. b
8. d
9. c
10. c
11. a
12. b
13. c
14. c
15. d

CH. 4

1. b
2. b
3. c
4. c
5. a
6. c
7. b
8. d
9. a
10. b
11. d
12. d
13. a
14. b
15. c

CH. 5

1. d
2. b
3. c
4. a
5. b
6. c
7. a
8. a
9. d
10. a
11. b
12. a
13. a
14. c
15. d
16. a
17. c
18. c
19. b
20. a

CH. 6

1. b
2. b
3. a
4. a
5. d
6. a
7. a
8. d
9. b
10. a
11. c
12. d
13. b
14. a
15. d
16. b

CH. 7

1. d
2. a
3. b
4. d
5. c
6. c
7. a
8. b
9. b
10. a
11. d
12. b
13. a
14. d
15. b

CH. 8

1. b
2. b
3. a
4. d
5. b
6. c
7. b
8. a
9. a
10. b
11. a
12. a
13. c
14. d
15. c

CH. 9

1. b
2. b
3. a
4. c
5. b
6. d
7. c
8. d
9. d
10. a
11. b
12. a
13. a
14. d
15. b

CH. 10

1. c
2. c
3. d
4. a
5. a
6. b
7. b
8. b
9. a
10. a
11. c
12. c
13. b
14. d

CH. 11

1. a
2. a
3. b
4. c
5. d
6. d
7. b
8. b
9. a
10. c
11. d
12. d
13. b
14. a
15. a

CH. 12

1. b
2. b
3. a
4. c
5. a
6. a

7. c
8. d
9. a
10. b
11. b
12. a

CH. 13

1. c
2. d
3. d
4. b
5. b
6. a

CH. 14

1. a
2. b
3. c
4. b
5. c
6. a
7. c
8. a
9. d
10. a

CH. 15

1. d
2. c
3. a
4. b
5. a
6. a
7. b
8. d

CH. 16

1. c
2. b
3. b
4. c
5. a
6. b
7. b
8. c
9. b
10. d

CH. 17

1. a
2. c
3. d
4. a
5. b
6. c

CH. 18

1. c
2. c
3. b
4. b
5. c
6. a
7. a
8. c
9. d
10. b
11. a
12. c
13. c
14. b
15. a
16. c
17. b
18. d
19. a
20. b

CH. 19

1. b
2. c
3. a
4. a
5. b
6. a
7. b
8. b
9. d
10. a
11. c
12. c
13. a
14. b
15. d

CH. 20

1. a
2. d
3. a
4. d
5. b
6. d
7. a
8. c
9. b
10. c
11. a
12. c
13. b
14. d
15. a
16. b
17. b
18. b
19. d
20. b
21. a
22. a
23. b
24. c
25. a
26. c
27. c
28. b

CH. 21

1. b
2. a
3. a
4. c
5. b
6. d
7. a
8. d
9. c
10. d
11. b
12. a
13. c

CH. 22

1. b
2. d
3. c
4. a
5. d
6. c
7. b
8. d
9. a
10. b
11. d
12. a
13. c
14. a
15. d
16. d
17. c
18. c
19. b
20. b

Ch. 23

1. d
2. c
3. a
4. a
5. b
6. d
7. b
8. a
9. b
10. c

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